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Natural Disturbance Bibliography for British Columbia

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John Parminter

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INTRODUCTION

This bibliography consists of journal articles, reports, conference papers, and theses that address natural disturbance regimes in British Columbia. The emphasis is on wildfire, but wind, insects, and diseases are also included to some extent. Many entries describe general disturbance history, landscape characteristics, and/or vegetation succession. Others are more detailed and provide disturbance dates or frequencies—especially for wildfire. Paleoecological studies go back thousands of years, while dendrochronological studies go back hundreds of years.

The entries are organized by biogeoclimatic zone, and where more than one zone is addressed by an entry it is repeated for each zone. Where the author(s) provided an abstract, it is usually reproduced verbatim (in quotes). Otherwise, text extracts (in quotes) are given or the pertinent information is summarized (not in quotes). In cases of multiple entries, such summary content may vary for a specific work depending on the biogeoclimatic zone for which it is entered. Where old biogeoclimatic codes are given, the current equivalent codes follow in brackets. Tree species codes are also translated into common names.

A few documents were not seen, so only basic citations were available. Hyperlinks are included for online material. Some older publications not currently online are available in hardcopy from the J.T. Fyles Natural Resources Library in Victoria (www.env.gov.bc.ca/nrs_library/index.html). Other more recent documents should be obtainable as PDF files from the respective authors.

The intent of this bibliography is to include most of the existing pertinent material up to late 2011 or early 2012.

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CONTENTS

Introduction iii
Alpine Biogeoclimatic Zones 1
Boreal White and Black Spruce Biogeoclimatic Zone.......... 1
Bunchgrass Biogeoclimatic Zone.......... 9
Coastal Douglas-fir Biogeoclimatic Zone.......... 11
Coastal Western Hemlock Biogeoclimatic Zone.......... 21
Engelmann Spruce – Subalpine Fir Biogeoclimatic Zone 45
Interior Cedar – Hemlock Biogeoclimatic Zone.......... 74
Interior Douglas-fir and Ponderosa Pine Biogeoclimatic Zones.......... 87
Montane Spruce Biogeoclimatic Zone 117
Mountain Hemlock Biogeoclimatic Zone.......... 134
Spruce – Willow – Birch Biogeoclimatic Zone 142
Sub-Boreal Pine – Spruce Biogeoclimatic Zone.......... 145
Sub-Boreal Spruce Biogeoclimatic Zone.......... 150

ALPINE BIOGEOCLIMATIC ZONES

Parminter, J. 1993. Fire history of Bowron Lake Park. B.C. Min. For., Res. Br., Victoria, B.C.

www.for.gov.bc.ca/hfd/library/documents/bib4291.pdf

"Fires can burn into the AT zone, usually originating at the lower elevations. An old burn on McCabe Ridge (between Bowron Lake and Isaac Lake) burned very high on the slopes and left evidence in the form of charred snags in the avalanche tracks."

"The 1898 burn at the west end of Tediko Ridge also burned high and its movement up the Bowron River valley was halted by an avalanche track which acted as a fuelbreak. Others such as the 1961 fire in Moxley Creek (the Wol fire) and the 1971 fire above Harold Creek (the Top fire) also burned to high elevations, as have a few other older fires as well. Depending on the type of alpine vegetation present, it may have a long recovery time."

BOREAL WHITE AND BLACK SPRUCE BIOGEOCLIMATIC ZONE

Annas, R.M. 1977. Boreal ecosystems of the Fort Nelson area of northeastern British Columbia. PhD thesis. Univ. British Columbia, Dep. Bot., Vancouver, B.C.

https://circle.ubc.ca/handle/2429/20578

"It is concluded that the cold boreal climate, flatness of the terrain, prevailingly fine textured soil parent material, and fairly frequent forest fires are the dominant environmental factors influencing ecosystem structure and dynamics in the study area."

"All the [trembling aspen – white spruce] stands studied originated after fire. This association can thus be considered as a 'pulsating' climatic fire climax which, in the Clementsian sense, is a sub-climax. Without fire, there are strong indications that the structure and composition of this association would change to one dominated by spruce…."

"It is thought that periodic forest fires (in the order of magnitude of one every 70 – 120 years) have helped to maintain the fine textured soils of upland sites in a highly productive state."

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 26.

www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh26.htm

"Forests predominate in the BWBS. Forest fires are frequent throughout, maintaining a variety of stand age classes and successional stages. 'Climax' forest is dominated by white spruce, sometimes with subalpine fir and minor black spruce. Most older stands have at least a few trembling aspen and lodgepole pine remaining. Seral stands of lodgepole pine, trembling aspen, and mixed white spruce – aspen are common. With severe, repeated fires, forests give way to a persistent scrub of willow and aspen."

"Grassland/scrub is locally common on south-facing slopes with coarse-textured soils. This site series is maintained by a combination of dry and nutrient-rich edaphic conditions and frequent fire. Stunted At [trembling aspen] and Pl [lodgepole pine], prickly rose, saskatoon, common juniper, Rocky Mountain juniper, kinnikinnick, pasture sage, and a mix of grasses (slender wheatgrass, purple reedgrass, and glaucous bluegrass) are typical."

Bartemucci, P., K.D. Coates, K.A. Harper, and E.F. Wright. 2002. Gap disturbances in northern old-growth forests of British Columbia, Canada. J. Vegetation Sci. 13(5):685–696. http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2002.tb02096.x/abstract

"We characterized the abundance, size and spatial patterning of canopy gaps, as well as gap-forming processes and light availability in boreal, sub-boreal, northern temperate and subalpine old-growth forests of northwestern British Columbia. The proportion of area in canopy gaps ranged from 32% in northern temperate forests to 73% in subalpine forests. Evenly distributed developmental gaps were dominant but permanent openings created by edaphic components and by shrub communities were also common, particularly in sub-boreal forests. Abundant gaps, large gap sizes, high numbers of gap makers per gap and frequent gap expansion events suggest that gaps have long tenure in these forests. Snapped stems and standing dead mortality were the most common modes of mortality in all forest types resulting in little forest floor disturbance, creating few germination sites for seedling establishment. We found high mean light levels (16 – 27% full sun) and little difference between non-gap and gap light environments. Our results suggest that gap dynamics in these forests differ fundamentally from those in temperate and tropical forest ecosystems."

Bartemucci, P., K.D. Coates, K.A. Harper, and E.F. Wright. 2002. Gap dynamics in old-growth sub-boreal and boreal forests of northwestern British Columbia. In: 4th International workshop on disturbance dynamics in boreal forests: disturbance processes and their ecological effects. Aug. 9–14, 2002, Prince George, B.C., p. 26.

"Old-growth stands comprise 33 and 42% of the forest land-base in the sub-boreal and boreal forests of northwestern BC, respectively. Wildfire is the major catastrophic disturbance in this landscape; however, the extent and importance of small-scale disturbances in older stands are not well described. We characterized the abundance, size and spatial patterning of canopy gaps, as well as the major gap-forming processes. The proportion of area in canopy gaps was 57 and 50% in sub-boreal and boreal forests, respectively. Gap sizes ranged from 19 to 830 m^2 in sub-boreal forests and 9 to 542 m^2 in boreal forests. Gaps were characterized as developmental, shrub, combination (developmental and shrub) or edaphic. Developmental canopy gaps were the most common in both forest types. Shrub gaps, dominated by Sitka alder (*Alnus sinuata*) were common in sub-boreal forests. The abundance of gaps, the large gap sizes, the high numbers of gap makers per gap, and the frequency of gap expansion events suggest that gaps have long tenure in these forests. Snapped stems and standing dead mortality were the most common modes of mortality, resulting in little forest floor disturbance. We found little difference between non-gap and gap light environments (18 – 27% full sun)."

Burleigh, J.S., R.I. Alfaro, J.H. Borden, and S. Taylor. 2002. Historical and spatial characteristics of spruce budworm *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae) outbreaks in northeastern British Columbia. For. Ecol. Manag. 168(1–3):301–309.
www.sciencedirect.com/science/article/pii/S0378112701007484

"The historical pattern of outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clem.), in white spruce stands in the Fort Nelson Forest District of northeastern British Columbia was reconstructed with the use of dendrochronology. Outbreaks occurred on an average every 26 years, with 5–6 outbreaks in the past century in the northern regions of the district, while southern regions experienced between 0 (the most southern sites) and 4 outbreaks. In the northern regions, outbreaks began about 10 years earlier and the period of defoliation was longer than in the southern regions of the district. The southern limit of the range of the spruce budworm in British Columbia is marked by the predominance of the Montane Boreal White and Black Spruce biogeoclimatic subzone that has cool and wet summers that may not favor budworm development. Therefore, outbreaks that begin in the more suitable northern habitat would move southward only when favorable environmental conditions develop. Along with the high number of outbreaks in the northern regions of the district, there has been no direct control of the budworm, and overmature stands are maintained through suppression of fire and lack of harvesting. Many of these stands are entering a state of general decline with protracted mortality, resulting from a complex of secondary insects and pathogens."

DeLong, S.C. 1998. Natural disturbance rate and patch size distribution of forests in northern British Columbia: implications for forest management. N.W. Sci. 72 (Spec. Issue No. 1):35–48.
www.vetmed.wsu.edu/org_nws/NWSci%20journal%20articles/1998%20files/Special%20addition%201/v72%20p35%20DeLong.pdf

"A common theme in current forest management policy is that harvesting should be designed to achieve the landscape patterns and habitat conditions that are maintained in nature by natural disturbance regimes. This study was undertaken to determine the influence of climate and topography on disturbance rate and patch size associated with stand replacement wildfire. The purpose was to provide new information to improve forest management guidelines based on approximating natural disturbances currently being implemented in British Columbia.

I modified stand age-class data from inventory records within a geographic information system in order to determine annual disturbance rate and patch size distribution for 9 areas differing in regional climate and topography (plateau vs. montane). Regression analysis was used to determine the influence of climate and gross topography on fire cycle. Patch size distribution was compared graphically and statistically.

Annual disturbance rate and patch size distribution in northern natural forests in British Columbia were clearly related to regional climate and topography. In montane landscapes, a decrease in disturbance rate, a decrease in mean patch size and a decrease in proportion of area in patches > 1,000 ha was associated with increasing precipitation. For plateau areas, topographic units with intermediate precipitation regime had higher disturbance rates and a greater proportion in patches > 1,000 ha. Montane areas which were climatically similar to adjacent plateau areas had a lower disturbance rate and less area in larger patches.

Current biodiversity guidelines appear to underestimate the fire cycle for many areas. Maximum allowable patch size in the current guidelines was lower than the maximum natural disturbance patch size determined for any of the landscapes examined. Current recommendations also suggest to manage for more area in 40–250 ha patches than was evident from the data."

DeLong, C. 2004. A field guide to site identification and interpretation for the north central portion of the Northern Interior Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 54.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh54.htm

"The BWBSdk1 occurs in the valley bottoms of the Omineca Mountains and Rocky Mountain Trench as far south as the Germansen River, as far north as the Turnagain River, as far east as the Rocky Mountain divide, and as far west as the divide east of Takla Lake." "Due to the fairly extensive fire history, forested areas are often seral forests dominated by lodgepole pine and/or trembling aspen. Hybrid white spruce and subalpine fir dominate in climax forests. Black spruce is common on upland sites with lodgepole pine on gentle slopes with a cool aspect and in wetlands."

DeLong, C., R.M. Annas, and A.C. Stewart. 1991. Boreal white and black spruce zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 237–250.
www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap16.pdf

"White spruce, trembling aspen, lodgepole pine, black spruce, balsam poplar, tamarack, subalpine fir, common paper birch, and Alaska paper birch are the major tree species in the forested sections of the BWBS. Forest fires are frequent throughout the zone, maintaining most of the forests in various successional stages."

"Frequent forest fires have formed a mosaic of upland forests of different ages in the BWBS. Conifers are often slow to re-establish after fire and deciduous forests of aspen and willow are commonplace and persistent. These deciduous forests are very productive habitats for ungulates, a wide selection of birds (including many of the warblers, thrushes, vireos, and flycatchers), and a variety of small mammals."

Jull, A.J.T. and M. Geertsema. 2006. Over 16,000 years of fire frequency determined from AMS radiocarbon dating of soil charcoal in an alluvial fan at Bear Flat, northeastern British Columbia. Radiocarbon 48(3):435–450.
https://journals.uair.arizona.edu/index.php/radiocarbon/article/view/2887

"We present results of radiocarbon dating of charcoal from paleosols and buried charcoal horizons in a unique sequence, which potentially records the last 36,000 yr, from a fan at Bear Flat, British Columbia (BC) (56°16′51″N, 121°13′39″W). Evidence for forest-fire charcoal is found over the last 13,500 ± 110 ^{14}C yr before present (BP) or 16,250 ± 700 cal BP. The study area is located east of the Rocky Mountains in an area that was ice-free at least 13,970 ± 170 ^{14}C yr BP (17,450–16,150 cal BP) ago. The latest evidence of fire is during the Medieval Warm Period (MWP). The charcoal ages show a periodicity in large fires on a millennial scale through the Holocene—an average of 4 fires per thousand years. Higher fire frequencies are observed between 2200 to 2800 cal BP, ~ 5500 and ~ 6000 cal BP, ~ 7500 to 8200 cal BP, and 9000 to 10,000 cal BP. These intervals also appear to be times of above-average aggradation of the fan. We conclude that fire frequency is related to large-scale climatic events on a millennial time scale."

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones of the Cassiar Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C. www.for.gov.bc.ca/hfd/library/documents/bib29004_book3.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal and north coastal forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The Cassiar Timber Supply Area contains a wide variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Some coastal sites are affected by fire very infrequently while interior boreal types are more susceptible to fire. Certain valley bottom alluvial sites have developed under the influence of primary successional processes but can nonetheless support fires. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones of the Cassiar Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib29004_book2.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the Cassiar Timber Supply Area by dividing the BWBS biogeoclimatic zone into 10 broad forest cover types for which 14 post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones and subzones of the Fort Nelson Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib27061_book4.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The Fort Nelson Timber Supply Area contains a wide variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Some alluvial sites have developed under the influence of primary successional processes but can nonetheless support fires. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones and subzones of the Fort Nelson Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib27061_book3.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the Fort Nelson Timber Supply Area by dividing the BWBS biogeoclimatic zone into five broad forest cover types for which 10 post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Parminter, J. 1983. Fire history and fire ecology in the Prince Rupert Forest Region. In: Prescribed fire–forest soils symp. proc., Mar. 2–3, 1982, Smithers, B.C. R.L. Trowbridge and A. Macadam (compilers and editors). B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Rep. 16, pp. 1–35.
www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Lmr016.htm

"Fire ecology knowledge is required for fire management operations as well as for other aspects of natural resource management. Natural fire has influenced ecosystem processes at various scales and has been a major factor in determining the composition and distribution of vegetation types. Different fire types and frequencies can be classed into fire regimes and these regimes related to the role of fire in different ecosystems.

Forest tree species and other vegetation possess varying degrees of fire tolerance and fire adaptations, or indeed may be totally dependent on fire for their continued existence. On the other hand certain vegetation species are fire sensitive and may be removed altogether or lessened in numbers by fire. It appears that fire has played a diverse role in the biogeoclimatic zones of the Prince Rupert Forest Region – from very rare in the Coastal – Cedars – Pine – Hemlock to very common in the Boreal White and Black Spruce. Post-fire vegetation development can follow one of several directions, the direction taken is determined by site characteristics, the nature of the fire, and subsequent environmental conditions.

Significant differences may exist between the natural fire regime and historical fire effects and the fire regime and fire effects imposed by man and his various land management activities. Guidance in the artificial application of fire can be obtained from a knowledge of the natural place of fire in the ecosystem in question."

"A lightning fire regime has historically influenced vegetation development.... Stand-replacement crown fires are the norm although surface fires have been common in some locales as a result of prescribed burning. Evidence of surface fires may also be found outside the perimeter of stand-replacement type burns where the fire's behaviour was moderated, affecting only the surface fuels.... The interval between fires on a given site can be as low as 20 to 30 years and the absence of stands much older than 200 years attests to the prevalence of fire."

Parminter, J. 1984. Fire-ecological relationships for the biogeoclimatic zones of the northern portion of the Mackenzie Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib25174_book3.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal and central northern forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The northern portion of the Mackenzie Timber Supply Area contains a variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1984. Fire-ecological relationships for the biogeoclimatic zones of the northern portion of the Mackenzie Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib25174_book2.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the northern Mackenzie Timber Supply Area by dividing the BWBS biogeoclimatic zone into five broad forest cover types for which 17 post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Parminter, J. 1991. Fire history and effects on vegetation in three biogeoclimatic zones of British Columbia. In: Fire and the environment: ecological and cultural perspectives. Proc. Int. Symp. Mar. 20–24, 1990, Knoxville, Tenn. S.C. Nodvin and A. Thomas (editors). U.S. Dep. Agric. For. Serv., Asheville, N.C. Gen. Tech. Rep. SE-69, pp. 263–272.
www.srs.fs.usda.gov/pubs/gtr/gtr_se069/gtr_se 069-section04.pdf

"The different fire regimes present in the province of British Columbia are well-illustrated by the Coastal Western Hemlock, Boreal White and Black Spruce, and Ponderosa Pine Biogeoclimatic Zones. Fires are variable in type, intensity, severity, effects, size, and interval. In the first two biogeoclimatic zones, stand replacement and/or partial stand replacement fires occur. Surface fires that maintain open forests with grassy understories are the historic norm in the Ponderosa Pine Zone.

Fire histories and fire effects have been determined for all three zones. In the Coastal Western Hemlock Zone the emphasis has been on fire history, stand establishment, and prescribed burning. Ecosystem-specific guides describing the type of fire suitable for silvicultural site preparation are widely available. Post-fire vegetation successional pathways have been developed for the Boreal White and Black Spruce Zone and are used to predict probable fire outcomes.

In recent times, the adverse implications of fire exclusion have been recognized in ecosystems such as those found in the Ponderosa Pine Zone. The reintroduction of fire through prescribed burning serves to address the problems and meet several resource management objectives."

Rogeau, M.-P. 2001. Fire history study—Mackenzie TSA, British Columbia. Prepared for Abitibi Consolidated Ltd., Mackenzie, B.C. Unpubl. rep.

"More than one fire regime was identified for the Mackenzie TSA. According to historical air photo information and Ministry of Forest fire occurrence statistics, trends in vegetation complexity, number of fires and age-class distribution, are best associated with the type of terrain." "The overall assessment revealed that the Rocky Mountain Trench is generally younger with a higher number of fires and a moderately to highly complex vegetation mosaic, the Interior Plateau is also fairly young, even more complex but with less fires. The Omineca Mountains are older, with a lesser number of fires than the Trench, but with a fairly similar vegetation complexity. Lastly, the Canadian Rockies, although affected by many fires, shows larger extents of older aged forest and a much lower vegetation complexity in general. In terms of forest age distribution, older forests are found in the mountains. The Cassiar Mountains, the Canadian Rockies and the Omineca Mountains show that 59, 53 and 49 percent of these forests respectively, are older than 140 years."

"The assessment of fire occurrence statistics in a regional context shows that the Mackenzie TSA is representative of the regional setting in terms of proportion of fire and burn area by fire size category." "When the information is evaluated by terrain types within the TSA, the Rocky Mountain Trench and Interior Plateau are the most lightning-caused fire prone and the Trench and the Upper Trench are by far the most prone to anthropogenic fires." "The lightning strike density distribution evaluated for the Greater TSA shows almost no correlation with the occurrence of lightning caused fires."

Blackwell, B.A., F. Steele, R.W. Gray, K. Iverson, and K. MacKenzie. 2001. Fire management plan—Churn Creek Protected Area. Prepared for BC Parks, Cariboo Distr., Williams Lake, B.C. Unpubl. rep.

"In one site in the BGxh3 in the Churn Creek Protected Area, low-severity fires as recorded on fire-scarred trees burned on average every 19 years. Fires could be even more frequent than this estimate as the BG is primarily not forested and many fires were likely not intense enough to scar the few trees." (cited by Wong et al. 2003 www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh53.htm)

Cawker, K.B. 1978. Historical dynamics of *Artemisia tridentata* Nutt. in southern British Columbia. PhD thesis. Simon Fraser Univ., Dep. Geog., Burnaby, B.C.
http://summit.sfu.ca/item/3171

"This study examines population demography and population history of *Artemisia tridentata* Nutt. in southern British Columbia. This shrub is a common rangeland weed, often occurring in dense stands and causing reduced forage yields by competition with desirable grass species. Although obviously well adapted to the environment of the study area at the present time, the species was apparently much less common during the middle and late nineteenth century, and its increased abundance since that time has been attributed to overgrazing by domestic livestock. Over the course of the last century, it is believed to have displaced the 'climax grasslands' of the area and replaced them with a 'sagebrush disclimax'. In spite of extensive study, the exact mechanism by which overgrazing induced this change has remained obscure, as have the major physical and biotic controls on the species' range and density.

This study was undertaken in an attempt to determine the environmental controls on the species' range and density, and to describe and explain the history of population changes in the study area. Analysis of the age structure of the existing population reveals a recruitment pattern that is highly irregular, apparently the result of temporal variations in seedling survival. Seedling survival and recruitment success are shown to be influenced by a variety of climatic factors, by the degree of grass competition, and by allelopathic suppression of seedlings by the established *Artemisia tridentata* population. Periods of good recruitment are correlated with periods of low fall and high winter temperatures, with high spring temperatures, with low precipitation and adequate moisture reserves in the fall, and with years of high moisture deficit, although early summer rain may be necessary to prevent seedling dessication. Grass competition appears to operate mainly through the restriction of bare mineral soil germination microsites, without which seedling mortality is high. Such sites may be created by grazing disturbance, rodent activity, or prolonged drought. Although this mechanism may provide a link between overgrazing and *Artemisia tridentata* invasion, the availability of suitable microsites does not appear to have been an important limiting factor in the field during the past ten years, and the natural availability of such microsites in the absence of grazing appears adequate to support a substantial population of *Artemisia tridentata* in the area. Allelopathic suppression by mature plants may serve to strengthen the modal age structure which derives initially from climatic variation, but is considered unimportant as a determinant of long-term population change.

Fire is capable of destroying established stands of *Artemisia tridentata*, and re-establishment of the species on burned areas is relatively slow. Seral stages may involve *Artemisia frigida* or *Artemisia tripartita*, which are more fire tolerant than *Artemisia tridentata*.

Population history was examined from documentary sources and the local pollen record. The documentary sources indicate an increasing abundance of shrubby *Artemisia* through the latter part of the nineteenth century, but both documentary and pollen evidence point to *Artemisia tripartita* as the chief increaser prior to about 1900, followed by an increase in the abundance of *Artemisia tridentata*. The pollen record indicates that the early settlement period was characterized by unusually low frequencies of *Artemisia*, and particularly *Artemisia tridentata* type pollen, and that pre-settlement populations approached or occasionally surpassed those of the present day. Substantial population levels were achieved in pre-settlement times in the absence of overgrazing by domestic livestock.

Local fire history is reconstructed using documentary records and quantitative estimates of the abundance of fine charcoal in the pollen samples. Fire frequency appears to have increased during the early settlement period, and to have declined after the early decades of this century. The pollen and charcoal records indicate a statistical relationship between fire occurrence and the abundance and species composition of the *Artemisia* population throughout the period of record. It is concluded that the low *Artemisia tridentata* population during the early settlement period was due to frequent range fire at that time, and that the recent increase in *Artemisia tridentata* abundance in this area is due chiefly to fire suppression rather than to overgrazing."

Cawker, K.B. 1983. Fire history and grassland vegetation change: three pollen diagrams from southern British Columbia. Can. J. Bot. 61(4):1126–1139. www.nrcresearchpress.com/doi/abs/10.1139/b83-120

"Recent vegetation change in the grasslands of southern British Columbia is examined using pollen analysis, and the results are compared with documentary records. The increasing dominance of the grasslands after 1890 by *Artemisia tridentata* and other woody shrubs has often been attributed to overgrazing by domestic livestock, but pollen data indicate that shrub populations were substantial in presettlement times, and that the recent 'invasion' represents a recovery from anomalously low population levels during the middle 19th century. These low *Artemisia* populations were probably due to a high frequency of fire in the early settlement period, and the subsequent recovery is probably related to fire suppression. Fire appears to have been an important element in the ecology of these grasslands over a long period, and it may have a place in modern management schemes."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 1. Very dry climatic region. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

In the PPBGa1 [BGxh2] along the lower elevations of the Thompson and Fraser rivers, "past fires and grazing use had a significant influence on the existing floristic composition of the ecosystems. Fire and grazing use provide the potential for a constant flux in the dominance of decreaser, increaser and invader species."

In the PPBGa2 [BGxw1] along the lower and middle elevations of the Douglas Lake area, "past fires and grazing use have had a significant influence on the existing floristic composition of the ecosystems. Fire and grazing use provide the potential for a constant flux of dominance of decreaser, increaser and invader species."

COASTAL DOUGLAS-FIR BIOGEOCLIMATIC ZONE

Banman, I. 2010. High-resolution fire and vegetation history of Garry oak ecosystems in coastal British Columbia. In: Garry Oak Ecosystems Recovery Team Research Colloquium. Mar. 4, 2010. Can. For. Serv., Pac. For. Cent., Victoria, B.C., pp. 22–23. www.goert.ca/documents/GOERT_Research_Colloquium_2010_Proceedings.pdf

"The deep-soil Garry oak meadows on southeast Vancouver Island were historically managed by First Nations for camas harvest, as foraging areas for elk and deer which were hunted, and also for the procurement of a variety of other plants for food and medicines. The main management tool used to maintain the open meadow or savannah structure was fire, which was used on a cyclical basis in order to control grasses, shrubs and conifer encroachment while promoting the growth of camas, which was a major food source. Since the cessation of routine burning more than 150 years ago when the first European settlers arrived, the remaining meadow fragments that have not disappeared due to urban expansion or agriculture have been invaded by agronomic grasses, native and non-native shrub and tree species and a host of other introduced plants."

Beckwith, B.R. 2002. Colonial Eden or indigenous cultivated landscape: reconstructing nineteenth century camas meadows on southern Vancouver Island. In: Garry oak ecosystem restoration: progress and prognosis. Proc. 3rd Annu. Meet. B.C. Chapter Soc. Ecological Restoration, Apr. 27–28, 2002, Victoria, B.C. P.J. Burton (editor), pp. 64–72.

"Early written accounts of southern Vancouver Island by European colonists often describe the landscape as a naturally or divinely made oak parkland. It is now widely recognized that much of the pre-European environment of the Victoria region consisted of open anthropogenic ecosystems. These cultural landscapes were shaped and maintained by thousands of years of Indigenous ecological management that included selective harvesting of root vegetables, weeding and clearing, and the widespread application of fire."

Benedict, R.E. 1915. Disposal of logging slash in British Columbia. In: Forest protection in Canada 1913–1914. C. Leavitt (compiler). Commission of Conservation, Canada. William Briggs Printers, Toronto, Ont., pp. 101–121. www.biodiversitylibrary.org/bibliography/51177#/summary

"The typical stand in this region is of even-age origin, dating from a fire, and is made up of varying proportions of Douglas fir, hemlock and cedar, with occasional admixture of spruce, white fir, lovely fir, and white pine. Where this typical stand escapes fire for a period of 400 years, the Douglas fir drops out, and, thereafter, the forest continues as an uneven-aged stand, the blanks being filled by reproduction of hemlock, cedar and lovely fir. Pure stands of hemlock are of frequent occurrence, and, occasionally, nearly pure stands of cedar are found."

Bjorkman, A.D. and M. Vellend. 2010. Defining historical baselines for conservation: ecological changes since European settlement on Vancouver Island, Canada. Conserv. Biol. 24(6):1559–1568. http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2010.01550.x/abstract

"Conservation and restoration goals are often defined by historical baseline conditions that occurred prior to a particular period of human disturbance, such as European settlement in North America. Nevertheless, if ecosystems were heavily influenced by native peoples prior to European settlement, conservation efforts may require active management rather than simple removal of or reductions in recent forms of disturbance. We used pre-European settlement land survey records (1859–1874) and contemporary vegetation surveys to assess changes over the past 150 years in tree species and habitat composition, forest density, and tree size structure on southern Vancouver Island and Saltspring Island, British Columbia, Canada. Several lines of evidence support the hypothesis that frequent historical burning by native peoples, and subsequent fire suppression, have played dominant roles in shaping this landscape. First, the relative frequency of fire-sensitive species (e.g., cedar [*Thuja plicata*]) has increased, whereas fire-tolerant species (e.g., Douglas-fir [*Pseudotsuga menziesii*]) have decreased. Tree density has increased 2-fold, and the proportion of the landscape in forest has greatly increased at the expense of open habitats (plains, savannas), which today contain most of the region's threatened species. Finally, the frequency distribution of tree size has shifted from unimodal to monotonically decreasing, which suggests removal of an important barrier to tree recruitment. In addition, although most of the open habitats are associated with Garry oak (*Quercus garryana*) at present, most of the open habitats prior to European settlement were associated with Douglas-fir, which suggests that the current focus on Garry oak as a flagship for the many rare species in savannas may be misguided. Overall, our results indicate that the maintenance and restoration of open habitats will require active management and that historical records can provide critical guidance to such efforts."

Brown, K.J. 2000. Late Quaternary vegetation, climate, fire history, and GIS mapping of Holocene climates on Southern Vancouver Island, British Columbia, Canada. PhD thesis. Univ. Victoria, School of Earth and Ocean Sci., Victoria, B.C.

www.nlc-bnc.ca/obj/s4/f2/dsk2/ftp03/NQ52755.pdf

"Pollen and microscopic charcoal fragments from seven sites (East Sooke Fen and Pixie, Whyac, Porphyry, Walker, Enos, and Boomerang lakes) were used to reconstruct the post-glacial vegetation, climate, and fire disturbance history on southern Vancouver Island, British Columbia, Canada. A non-arboreal pollen and spore zone occurs in the basal clays at Porphyry Lake and likely represents a tundra or tundra-steppe ecosystem. This zone precedes the *Pinus contorta* (lodgepole pine) biogeochron that is generally considered to have colonised deglaciated landscapes and may represent a late Wisconsinan glacial refugium. An open *Pinus contorta* woodland characterised the landscape in the late-glacial interval. Fires were rare or absent and a cool and dry climate influenced by 'continental-scale katabatic' easterly winds dominated. Closed lowland forests consisting of *Picea* (spruce), *Abies* (fir), *Tsuga heterophylla* (western hemlock), and *Tsuga mertensiana* (mountain hemlock) with *P. contorta* and *Alnus* (alder) and sub-alpine forests containing *Picea*, *Abies*, and *T. mertensiana* with *P. contorta* replaced the *P. contorta* biogeochron in the late Pleistocene. Fires became more common during this interval even though climate seems to have been cool and moist. Open *Pseudotsuga menziesii* (Douglas-fir) forests with *Pteridium* (bracken fern) in the understory and *Alnus* in moist and disturbed sites expanded westward during the warm dry early Holocene.

At this time closed *Picea*, *T. heterophylla*, and possibly *Alnus* forests grew in the wettest part of southern Vancouver Island at Whyac Lake. At high elevations, forests consisting of *T. heterophylla* and *Pseudotsuga* coupled with *Alnus* expanded during the early Holocene. Fires occurred frequently in lowland forested ecosystems during this interval, although East Sooke Fen in a dry, open region experienced less fire. At high elevations, charcoal increased somewhat from the late Pleistocene, indicating slightly more fires and reflecting continued moist conditions at high elevations. The mid and late Holocene was characterized by increasing precipitation and decreasing temperature respectively. Mid Holocene lowland forests were dominated by *Pseudotsuga* with *T. heterophylla* and *Alnus* in southeastern regions, *T. heterophylla* and *Thuja plicata* (western red-cedar) in southern regions, and *T. heterophylla* and *Picea* in southwestern regions. An overall decrease in charcoal influx suggests a decrease in lowland fires, although locally isolated fire events are evident in most sites. *Quercus garryana* (Garry oak) stands spread westward during the mid Holocene, attaining maximum extent between East Sooke Fen and Pixie Lake, approximately 50 km beyond their modern limit. Lowland sites record a general decrease in fires at this time. At high elevation, mid Holocene forests were dominated by *T. heterophylla*, *Picea*, and *Abies* with *Alnus*. An overall increase in charcoal influx at high elevations may reflect an increase in the number of charcoal fragments entering the basins by overland flow as opposed to an increase in fire incidence because climate was moister.

In the late Holocene, closed *T. heterophylla* and *T. plicata* forests became established in wetter western regions, *Pseudotsuga* forests occupied drier eastern portions, and *T. mertensiana* and *Cupressaceae*, likely *Chamaecyparis nootkatensis* (Alaska yellow cedar), forests were established in sub-alpine sites. Lowland fires were infrequent in wet western regions but frequent in drier eastern regions. A slight reduction in charcoal influx generally occurs at high elevations, implying fewer fires. A recent increase in charcoal influx at East Sooke Fen and Whyac, Walker, Enos, and Boomerang lakes may reflect anthropogenic burning. Holocene paleoclimates were reconstructed at 1,000 year intervals through a geographic information system (GIS) using contemporary climate data and surface and fossil pollen assemblages by establishing empirical regression equations that calibrated contemporary precipitation and temperatures to present day Douglas-fir-western hemlock (DWHI) and *T. heterophylla-T. mertensiana* (THMI) pollen ratios."

Brown, K.J. and R.J. Hebda. 2002. Ancient fires on southern Vancouver Island, British Columbia, Canada: a change in causal mechanisms at about 2,000 ybp. Environ. Archaeol. 7(June):1–12.
www.ingentaconnect.com/content/maney/env/2002/00000007/00000001/art00001

"Charcoal records were examined from seven sediment cores and two stratigraphic sections on southern Vancouver Island, Canada. Charcoal influx and climate trend regressions were established using high order polynomial functions. During the late-glacial (ca. 13,000–10,000 ybp), variations in the charcoal record suggest that fires likely responded to changes in fuel availability and climate. The high incidence of early-Holocene (ca. 10,000–7,000 ybp) fires may have been partly modified by human activity, though it seems more likely that climate exerted the greatest control. A decrease in fires during the mid- and early late-Holocene from 7,000–4,000 and 4,000–2,000 ybp respectively is consistent with a regional moistening trend, implying that fires were climatically limited. In the late late-Holocene from 2,000 ybp–present, several sites record an increase in charcoal influx even though climate was continuing to moisten and cool, suggesting that non-climatic factors were responsible for the observed increase in fire activity. Estimates of native populations range up to thousands of people for southern Vancouver Island before the arrival of Europeans. These people were knowledgeable of fire, suggesting that humans were responsible for the increase in fires during the late late-Holocene cool, moist interval."

Eis, S. and D. Craigdallie. 1980. Gulf Islands of British Columbia, a landscape analysis. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Inf. Rep. BC-X-216.
www.cfs.nrcan.gc.ca/publications?id=2058

Slash burning, carelessness, land clearing by settlers, and accidents account for an extensive fire history. Charcoal in the soil indicates that most of the study area was burned, many places repeatedly. Hills, after logging and burning, were used for grazing but eventually regenerated to trees. This re-invasion of the forest often took many years because settlers used fire repeatedly to fight the re-invading forest and to encourage the growth of grasses and vetches in order to improve pasture (Galiano, Mayne, Saturna, North and South Pender, and Prevost Islands).

Eis, S. and E.T. Oswald. 1975. The Highland landscape. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Inf. Rep. BC-X-119.
www.cfs.nrcan.gc.ca/publications?id=3980

From the amount of charcoal in the soil, it appears that the area has had an extensive fire history. Fires in 1854 and 1860, probably caused by humans, killed all small trees on an area of at least 240 ha north and west of Florence Lake and opened the stands for grazing sheep and cattle. The area was periodically re-burned to suppress shrubs and encourage vetches. South of McKenzie Lake, a fire in 1885 destroyed all trees on an area of more than 200 ha. Smaller fires were frequent throughout the area.

Fuchs, M.A. 2001. Towards a recovery strategy for Garry oak and associated ecosystems in Canada: ecological assessment and literature review. Can. Wildl. Serv., Pac. Yukon Region. Tech. Rep. GBEI/EC-00-030.
www.goert.ca/documents/litreview.pdf

Fire history and fire ecology in Garry oak and related grasslands and mixed forests have been investigated since 1932 in California, Oregon, Washington, and, to a lesser extent, in British Columbia. "These studies document the ubiquitous use of fire by First Nations prior to European settlement. The functions of these management activities varied from place to place, but for the most part were associated with directly enhancing important food resources or improving the ease of capture or collection.... The precise characteristics of the fires is largely unknown, but historical accounts and dendroecological analyses indicate that they were ignited in late summer and fall, that they burned frequently, perhaps annually in some places, and covered large expanses of the landscape. This regular fire regime prevented the buildup of fuels, and consequently fires were generally flashy and low intensity, carried quickly through the landscape by the dry herbaceous understorey."

Gedalof, Z., M. Pellatt, and D.J. Smith. 2006. From prairie to forest: three centuries of environmental change at Rocky Point, Vancouver Island, British Columbia. N.W. Sci. 80(1):34–46.
www.vetmed.wsu.edu/org_NWS/NWSci%20journal%20articles/2006%20files/Issue%201/05%20Gedalof.pdf

"Garry oak (*Quercus garryana*) savannas are among the most endangered ecosystems in Canada. In coastal British Columbia the vast majority of Garry oak savannas have been developed for residential, agricultural, or industrial use. Much of the remaining habitat is threatened by conifer encroachment or invasion by exotics. In this study tree-ring analysis was used to reconstruct stand composition and structure of an oak savanna at Rocky Point, on southern Vancouver Island, British Columbia. At the time of European settlement, the site was largely open prairie, with a few scattered oak trees. Establishment of Garry oak at Rocky Point began shortly after settlement of the area by Europeans—probably due to the cessation of frequent burning by indigenous peoples. Since the 1950s, however, Douglas-fir and grand fir have been encroaching on the Garry oak savanna. The causes of this invasion are unclear, but the invasion signals a clear transition in the stand structure and composition. Oak seedlings are abundant, but few saplings exist—suggesting that oak is not regenerating at Rocky Point. Mechanical removal of conifers would help maintain the Garry oak community over the near future, but given the nearly complete lack of oak recruitment, some restoration of ecosystem processes—most likely fire—will be required to maintain a functioning Garry oak ecosystem. This management strategy will be severely constrained by changes in stand structure resulting from decades of fire exclusion, the potential for weedy exotics to invade the post-fire communities, and the presence of an ammunition depot nearby."

Heusser, L.E. 1983. Palynology and paleoecology of postglacial sediments in an anoxic basin, Saanich Inlet, British Columbia. Can. J. Earth Sci. 20(5):873–885.
www.nrcresearchpress.com/doi/abs/10.1139/e83-077

"Varved, black clayey silts deposited in the marine waters of Saanich Inlet yield unusually abundant and diverse pollen assemblages derived from the coastal Douglas-fir (*Pseudotsuga*) and western hemlock (*Tsuga heterophylla*) forests of southwestern British Columbia.

The 12 000 year palynological record chronicles the development of vegetation since ice left Saanich Inlet: the succession of pine (*Pinus contorta*) and alder (*Alnus rubra*) woodlands by forests characterized by Douglas-fir and oak (*Quercus*) and later by western hemlock and red cedar (*Thuja plicata*). Rapid deposition of annual layers of pollen, charcoal, and other terrigenous particles provides detailed evidence of changes in land use during the past few hundred years: settlement, logging, farming, and urbanization. Vegetational and climatic changes inferred from pollen spectra in the marine sediments of Saanich Inlet compare favorably with changes inferred from correlative pollen assemblages previously described from adjacent parts of Vancouver Island and the Fraser River valley."

Lucas, J. and T. Lacourse. 2012. Vegetation history in a dry Douglas-fir ecosystem. In: Garry Oak Ecosystems Recovery Team Research Colloquium. Feb. 17, 2012. Can. For. Serv., Pac. For. Cent., Victoria, B.C., p. 11.
www.goert.ca/documents/GOERT_Research_Colloquium_2012_Proceedings.pdf

"Paleoecological studies can provide high resolution records of forest dynamics over long temporal scales that can help inform management and conservation of protected areas, particularly in relation to vegetation responses to changing climate and fire regimes. A 9 m lake sediment core was collected from Roe Lake on North Pender Island to document long-term changes in forest composition and fire regime using fossil pollen and charcoal analyses in combination with radiocarbon dating. Preliminary data from pollen analyses show that early Holocene open woodlands were dominated by *Pseudotsuga menziesii*, *Alnus rubra*, and various herbaceous and fern species. *Pseudotsuga menziesii*, *Quercus garryana*, and *Alnus* spp. dominated increasingly closed middle and late Holocene forests, and were accompanied by *Thuja plicata* and *Acer macrophyllum*. *Q. garryana* reached maximum abundance on North Pender Island between about 7500 to 5000 calendar years before present. Charcoal analyses on the same sediments will reveal the island's long-term fire history and provide a fire return interval that could aid management of the dry forests of southwestern British Columbia."

McCoy, M.M. 2006. High resolution fire and vegetation history of Garry oak ecosystems in British Columbia. MSc thesis. Simon Fraser Univ., Dep. Biol. Sci., Burnaby, B.C.
http://ir.lib.sfu.ca/handle/1892/3415

"I used fossil pollen and macroscopic charcoal in sediments extracted from three lakes to investigate the effects of climate and human activity on fire regimes and vegetation of Garry oak ecosystems in British Columbia. Sediment records from Roe Lake and Quamichan Lake span the past 250 calendar years, while the Florence Lake record spans 560. Roe and Quamichan charcoal records exhibit similar fire patterns and correspond to other fire records in the Pacific Northwest, indicating climate-driven responses. After ca. 1870, European agriculture, logging, and fire suppression dominate the fire and vegetation history at Roe and Quamichan lakes. Variations in pollen abundance and species composition confirm forest clearance and exotic plant introductions. Florence Lake data also correspond well with regional climate, until ca. 1800. These results show that, up until the mid-1800s, fire and vegetation histories varied in response to climate; thereafter, cultural activities appear to have dominated disturbance regimes."

McCoy, M.M., M.G. Pellatt, and R.W. Mathewes. 2005. High-resolution fire and vegetation history of Garry oak ecosystems in coastal British Columbia. In: Garry Oak Ecosystems Recovery Team Research Colloquium. Feb. 25, 2005. Can. For. Serv., Pac. For. Cent., Victoria, B.C. p. 10.
www.goert.ca/documents/GOERT_Research_Colloquium_2005_Proceedings.pdf

"We used macroscopic charcoal (> 125 µm diameter) and fossil pollen from two ^{210}Pb-dated lake sediment cores to reconstruct local fire and vegetation histories within the northern range limit of Garry oak (*Quercus garryana*) ecosystems (GOEs), from ca. 1748 AD to present, at 2–5 year intervals. Several peaks in charcoal abundance prior to European settlement are interpreted as wildfires. Post-1860 charcoal peaks are interpreted as mainly land clearing fires. A significant decline in charcoal abundance after ca. 1935 is attributed to fire suppression. Variations in pollen abundance and species indicate land clearing and related disturbances; introduced exotics were also found."

McCoy, M.M., M.G. Pellatt, and R.W. Mathewes. 2006. High-resolution fire and vegetation history of Garry oak (*Quercus garryana*) ecosystems in coastal British Columbia. In: Garry Oak Ecosystems Recovery Team Research Colloquium. Feb. 24, 2006. Can. For. Serv., Pac. For. Cent., Victoria, B.C., pp. 6–7.
www.goert.ca/documents/GOERT_Research_Colloquium_2006_Proceedings.pdf

"Fossil pollen and macroscopic charcoal (>125 µm) from sediments of three lakes were used to investigate effects of climate and human activity on fire and vegetation histories of Garry oak ecosystems (GOEs) in coastal British Columbia. Sediment records from Roe and Quamichan Lakes span the last 250 years; Florence Lake's record spans the last 560 years. Sampling intervals span 3 to 10 yrs.

Roe and Quamichan records show low fire activity before ca. 1780 AD. Increased fire frequency and variability ca. 1780-1860 reflect climate instability observed elsewhere in the region, and possibly changes in First Nation burning practices. Following a large fire event, Garry oak at Quamichan Lake decreases significantly ca. 1830 and does not recover. Following European settlement ca. 1860, fire event frequency decreases but overall charcoal abundance increases, indicating slash burning for agriculture and logging. After ca. 1940, charcoal abundance declines, reflecting active fire suppression. Grasses also increase at this time. Variations in pollen abundance and species composition confirm forest clearance and introduction of exotic plants.

At Florence Lake, oak is present from ca. 1440-1620 at low abundance. After ca. 1620, during and following a prolonged period of regional fire activity, oak and alder (*Alnus* spp.) increase. From ca. 1720 oak remains stable, until ca. 1925 when it decreases significantly, during extensive logging. Florence Lake charcoal record corresponds well with regional climate data until ca. 1850, when logging, followed later by suburban development, become the primary disturbances.

This research shows that the fire and vegetation histories in the study area have varied in response to climate and possibly First Nations activities, but ecosystem response has become decoupled from these disturbance factors by modern land-use activities."

McDadi, O. and R.J. Hebda. 2006. Change in historic fire disturbance in a Garry oak (*Quercus garryana*) meadow and Douglas-fir (*Pseudotsuga menziesii*) mosaic, Univ. of Victoria, British Columbia, Canada: a possible link with First Nations and Europeans. For. Ecol. Manag. 256(10):1704–1710.
www.sciencedirect.com/science/article/pii/S037811270800248X

"We investigated late Holocene vegetation and fire changes on southeast Vancouver Island, British Columbia, through high-resolution analysis of pollen, spores and charcoal contained within a forest soil. Located in the Mystic Vale Endowment lands, University of Victoria campus, the site occurs adjacent to Garry oak (*Quercus garryana*) meadows within a Douglas-fir (*Pseudotsuga menziesii*) forest regionally influenced by First Nations burning. The age of the sequence is estimated from the occurrence of non-native plantain (*Plantago* spp.) pollen, between the early 19th century and the present. Prior to the 1850s, the Mystic Vale supported a Douglas-fir forest with a sword fern (*Polystichum munitum*) understory. Low intensity fires may have burned either at or near the site, but did not destroy the stand. From the time of European settlement (ca. 1850s to 1872) to the early 20th century, Douglas-fir forests with a sword fern understory persisted but with more openings than in the past. Adjacent forests were cleared leading to successional stands of red alder (*Alnus rubra*). The site may have supported more grasses near or after 1872 because of adjacent cultivation and the introduction of livestock. Local establishment of Garry oaks at the margin of a field adjacent to the deposition site may have occurred at this time. The strong charcoal signal may be attributable to clearing and local fires of European settlers. Exotic weedy species such as plantain arrived during this time. From about the mid 20th century to the present a closed canopy Douglas-fir forest returned. Pre-

European charcoal concentrations were significantly greater than modern-day charcoal concentrations. Peak charcoal concentrations coincided with the onset of European settlement in the area, a period in which land-clearing is thought to have been aided by the use of fire. This study suggests that the observed changes in charcoal concentrations in pre- and post-European contact time may be linked with a switch from aboriginal to European ignition sources. The study provides a historical impetus to consider partially restoring parts of southeast Vancouver Island by reintroducing fire via the application of controlled burns."

Pellatt, M.G., Z. Gedalof, M. McCoy, K. Bodtker, A. Cannon, S. Smith, B. Beckwith, R. Mathewes, and D. Smith. 2007. Fire history and ecology of Garry oak and associated ecosystems in British Columbia: final report for the interdepartmental recovery fund project 733. Parks Can., West. and North. Serv. Cent., Winnipeg, Man.
www.for.gov.bc.ca/HFD/library/documents/Pellatt_etal_2007.pdf
"Under the Canadian Species at Risk Act (SARA), Garry oak (*Quercus garryana*) ecosystems are listed as 'at-risk' and act as an umbrella for over one hundred species that are endangered to some degree. In order to effectively recover or allow these species to persist where possible, it is critical to understand the ecological processes that are essential to their ongoing survival. This report describes a multi-disciplinary research project that examines the paleoecology, modern ecology, and fire history of selected Garry oak ecosystems. Understanding mean fire return intervals (MFRI), ecosystem dynamics over time, and the role of people in this ecosystem structure is critical to the success of programs that are designed to ensure the long-term survival of these communities. The MFRI, inferred from charcoal analysis, ranges from 26 years at Quamichan Lake, to 27 years at Roe Lake and 41 years at Florence Lake. Dendroecological analysis indicates that, as a whole, Garry oak populations are not surviving to the sapling stage at the study sites. Strong recruitment has not occurred since the late-1800s and early 1900s. Fire suppression, shading by conifers, and changes in grazing patterns are likely causes of this phenomenon. Bioclimatic envelope modeling of Garry oak in BC, Washington, and Oregon was undertaken in this study. Based on the climate of the recent past and the current distribution of Garry oak, climate suitability for the current Garry oak range in BC will decrease in the near future, then will improve within this century, but not to current suitability values. All models we tested concur, although the forecasts from GCMs differ in magnitude of range expansion. Bioclimatic models can be configured to quantify and map the potential expansion or contraction of species ranges, but this depends upon assigning a numeric threshold to transform relative suitability scores into species presence/absence. Choosing the best threshold is somewhat arbitrary since we lack the data to verify potential future distributions, so we report change in climate suitability. These results are consistent with paleoecological studies that show that maximum northern range for Garry oak was limited to the Georgia Depression during the Holocene. Albeit edaphic, disturbance, competition, and dispersal factors are not considered in this model, the distribution of Garry oak in the various climate envelopes is likely a realistic range for Garry oak distribution in the future."

Roemer, H.L. 1972. Forest vegetation and environments on the Saanich Peninsula, Vancouver Island. PhD thesis. Univ. Victoria, Dep. Biol., Victoria, B.C.

www.for.gov.bc.ca/hfd/library/documents/bib1024.pdf

"It appears that these forests, especially the oak-grass forests are too open to develop the intense heat which is necessary to burn out the organic matter and expose the mineral soil to erosion. However, there is plenty of evidence for the occurrence of fires in such stands by the high charcoal content of A and upper B horizons. While these fires may not be very severe they seem to be much more frequent than in coniferous communities."

"That a shade-intolerant species dominates the climax association is a result of the frequency of forest fires. As already pointed out all major *Pseudotsuga* stands have originated after fires. Large forest fires occurred naturally on the average every 200 to 300 years. Because of this Davis (1959, p. 22) and Heusser (1960, p. 60) call the *Pseudotsuga* forest a subclimax. However, if the natural occurrence of fires is accepted as a feature of the macroclimate, the *Pseudotsuga* forest may also be regarded as a climatic climax community."

Schmidt, R.L. 1960. Factors controlling the distribution of Douglas fir in coastal British Columbia. Q. J. For. 54(2):156–160.

"The examination of many natural Douglas fir forests throughout its entire coastal range indicated that one principal factor is common to all habitats supporting high populations of Douglas fir; namely, a history of repeated forest fires since glacial recession. A denuding factor such as forest fire was a necessity in nature for the regeneration of Douglas fir because insufficient light and unfavourable soil conditions beneath a closed forest canopy precluded successful abundant regeneration of this species. In the long-continued absence of such a denuding factor, more shade tolerant species would replace Douglas fir and eventually control the habitat. Confirmation of fire history is made evident by the presence of charcoal at the surface of the mineral soil, and on the bark of veteran Douglas fir trees which survived the fire, and by the even-aged character of the stands.

Since Douglas fir regenerates soon after a fire, it is possible to establish the date of fire occurrence by obtaining ages of the largest Douglas fir trees. A considerable portion of the coast forest was sampled by this means resulting in data on the frequency and extent of past forest fires. Of particular significance was the discovery that on Vancouver Island alone, around 2 million acres [809 400 ha] of forest were burned by fires between 300 and 400 years ago. The history of other extensive fires was traced back to 1300 years ago. The forested areas burned by these fires were not identical, so that today examples of each age class are evident in many parts of the range of this species, and provide an excellent opportunity for long-term successional studies.

The incidence of forest fires was next evaluated in terms of climate, and it was found that the geographic range of Douglas fir is controlled by low summer precipitation, high summer temperatures and the frequency of severe summer lightning storms. Periodically, perhaps every 200 to 300 years for most coastal areas, these elements combined to set the stage of forest fires which denuded extensive tracts of land. However, the migration of Douglas fir to all areas of high fire occurrence, especially in northern mainland forests has been halted by intrusions of low fire risk areas."

COASTAL WESTERN HEMLOCK BIOGEOCLIMATIC ZONE

Acres International Ltd. 1993. GVWD watershed ecological inventory pilot study (Jamieson–Orchid–Elbow drainage). Prepared for Greater Vancouver Watershed District, North Vancouver, B.C.

"The age class distribution of stands within the Jamieson Creek study area, below 600 m, suggest that a large portion of this area may have been fire-generated. Many of the stands below 600 m are dominated by 300 to 350 year old cedars with scattered 800–1000 year old cedar veterans. The past occurrence of fire in these stands is further supported by the presence of burned cedar snags representative of the older age class (800–1000 years old)."

"Over much of the study area, especially at elevations above about 700 m, there is no evidence of stand-replacing disturbance and old growth forest predominates. At these elevations the forest is composed almost entirely of climatic and edaphic climax stands where disturbance is very localized. Windthrow or small landslides create small gaps in the canopy and advanced regeneration growing under the canopy responds to fill the gap with new trees. It is expected that stand composition and structure will remain more or less the same in these stands for a very long time." "In the CWHvm2 variant montane species such as western hemlock, western redcedar, and amabilis fir occur with mountain hemlock and yellow cedar, and reflect the transitional climate of this variant.

The mosaic of stands below about 700 m reflects a complex history of stand-replacing disturbance by fire, landslides, and harvesting. Much of the area at lower elevations is covered by a single old growth stand type in which large western redcedar dominates the upper canopy, along with western hemlock and amabilis fir. Although not confirmed from observations within the study area, it appears that this stand type has regenerated after a large fire that occurred about 450 years ago, and swept through much of the lower elevations within the study area.

Two smaller fires that occurred about 180 and 220 years ago, have resulted in two stands representing mature forest successional stages. In one case the stand is dominated by western redcedar, while the other has regenerated to a western hemlock stand. Standing snags with pronounced fire scars provide excellent evidence in both of these stands. These two stands provide examples of small (1.3 and 2.3 ha), relatively frequent fires, that are initiated by lightning, and burn over a small area before extinguishing themselves.

A number of stands that have regenerated after landslides are also present at low elevations in the study area, and are dominated by western hemlock. These stands are at Mature Forest and Old Growth successional stages and reflect several major landslide events."

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforests of southern British Columbia. PhD thesis. Univ. British Columbia, Dep. Bot., Vancouver, B.C.

https://circle.ubc.ca/handle/2429/8733

"I examined the effects of natural and anthropogenic disturbances on the patterns of species composition, tree regeneration, and forest architecture in old-growth forests from southern coastal British Columbia. This study was conducted in the submontane portion of the Coastal Western Hemlock Zone in the Vancouver watersheds, Pacific Spirit Park, and Clayoquot Sound.

In the greater Vancouver area, old forests (250 yr) exhibited greater structural and compositional heterogeneity than young (31–60 yr) and mature (61–80 yr) forests. Size class distributions of living and dead standing trees in the three age groups suggested both qualitative and quantitative differences in regeneration and mortality processes. The canonical correlation between structure and composition was high (Rc = 0.84) but a substantial amount of total variation remained unexplained by the analysis. PCA (principal component analysis) axis 1 of species composition separated the lower elevation (warmer/drier) mature forests from the higher elevation (cooler/wetter) young and old forests. PCA axis 1 of structure separated the young and mature forests from the old forests.

Stand history reconstructions in the Capilano watershed and Clayoquot Sound indicated that frequent small-scale disturbances (0.1–0.2 treefalls/year) and relatively slow growth rates explain the relatively open character and complex architecture of old-growth cedar-hemlock forests. All three study plots exhibited reverse-J tree size distributions considered indicative of climax or steady-state conditions; however, age structures showed important differences. One plot originated from a fire 300 yr ago while the other two were over 1000 years old and showed no signs of catastrophic disturbances.

Gap-phase dynamics may influence patterns of tree regeneration if small-scale disturbance events are relatively close in space and time. However, the spatial pattern of understory trees was not significantly correlated with canopy structure. Thus, the role of gap-phase dynamics appears to be more important as a release mechanism for suppressed trees already established in the understory.

The presence of standing water had a strong influence on the spatial pattern of understory plant communities. In addition, bryophyte species composition was related to stand structure and dynamics as evidenced by a succession gradient on wood.

Except for Douglas-fir, which appears to require large scale disturbances for its regeneration, all other tree species examined are well adapted to a range of disturbances. This indicates that coastal silviculture could use a diversity of cutting methods analogous to natural disturbances instead of relying solely on clearcutting. The estimated forest turnover time varied between 375 and 1096 yr, based on the present proportion of area in canopy gaps (39%), and the estimated time to fill canopy gaps. Tree ring signatures revealed 208 yr–326 yr are needed for small disturbances to have a noticeable effect on tree growth for an area equivalent to the size of the study plots (1/2 ha).

At the landscape level, the main catastrophic disturbance in the Capilano watershed before logging was fire. Large scale fires were associated with warm south facing slopes and occurred at low frequencies (ca. 600 years). The fire regime also coincided with periods of low sunspot activity. Logging has significantly changed the ecology of disturbance and patch dynamics in the Capilano watershed. A slow recovery process following the impact from human disturbances and a trend towards unprecedented levels of forest fragmentation supports concerns regarding conservation in our coastal forests."

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 26.

www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh26.htm

"Because fires occur rarely in our CWH, seral stands were uncommon before clearcut logging began on a large scale. Across most of the zone, shade-tolerant conifers such as western hemlock, amabilis fir, and western redcedar dominate young stands and regenerate quickly after clearcutting or windthrow. Inland, however, some south-facing slopes and drier valleys such as the Kitsumkalum have a history of fire. Lodgepole pine, paper birch, and trembling aspen are well established in such areas."

Beese, W.J. and J.S. Sandford. 1992. Age of old-growth forests on Vancouver Island. B.C. Min. For., Contract # 98444. Prepared for B.C. Min. For., Vancouver Forest Region, Nanaimo, B.C. Unpubl. rep.

"This study characterized the age of dominant trees in old-growth forests on Vancouver Island using existing data. Individual tree age, height, diameter and site data from a variety of sources were assembled in a common database representing 789 plots and 3866 individual trees. A map of plot locations was produced at 1:380 160 scale.

Most dominant and codominant trees in old-growth forests on Vancouver Island are 150 to 350 years old. The median tree age was 253 years, with a slightly higher mean of 270 years. The frequency of trees over 350 years old diminishes rapidly. Trees over 500 years old are uncommon, and trees over 700 years old are rare.

All-aged stands are common on Vancouver Island. Most stands have a wide range of ages represented among dominant and codominant trees. Actual time since major disturbance is much greater than stand median or mean ages indicate. Most forests on Vancouver Island have the potential for sustaining old-growth conditions over long periods with gradual replacement of individual trees.

Windthrow appears to maintain somewhat younger stands on the windward portion of Vancouver Island than the leeward portion, but with a wide range in ages within stands. The northern tip of the island has the youngest median stand ages. The northern leeward portion of the island tends to have stands with older median age, possibly due to less frequent fire and windthrow compared to other regions of the island. Median stand age tends to be greater in higher elevation biogeoclimatic variants, with elevational trends more pronounced for windward areas.

The major conifer species on Vancouver Island can be ranked from longest-lived to shortest-lived in the following order: yellow-cedar, Douglas-fir/western redcedar, western hemlock/mountain hemlock, amabilis fir, Sitka spruce and lodgepole pine.

The characteristics of Vancouver Island forests suggest the following criteria for old-growth definitions:

- a minimum median stand age of 200 years for all submontane biogeoclimatic units.
- higher minimum stand age (250 years) for the Mountain Hemlock zone and montane Coastal Western Hemlock variants.
- age spread among dominant trees of at least 80 years.

To obtain data on age structure for all size classes within stands, sampling of clearcut old-growth stands by geographical area, biogeoclimatic zone and elevation was undertaken in summer 1991 by two exchange students from Germany, Rudiger Stoltz and Dirk Schiedemann. These data will be presented in a student thesis, and combined with this report for publication."

Brown, K.J. and R.J. Hebda. 1998. Long-term fire incidence in coastal forests of British Columbia. N.W. Sci. 72 (Spec. Issue No. 2):64–66. www.vetmed.wsu.edu/org_NWS/NWSci%20journal%20articles/1998%20files/Special%20addition%202/v72%20p64%20Brown%20and%20Hebda.pdf

"Fossil charcoal and pollen collected from several sites around southern Vancouver Island show that vegetation composition and fire activity have varied considerably during the late Pleistocene and Holocene. Our results reveal that natural disturbance regimes of coastal forests were strongly shaped by climate, vegetation composition, and possibly human activity. Future forest disturbance and successional patterns may differ considerably from those of the recent past and become more comparable to those of the early Holocene Xerothermic or pyrothermic as the global warming trend progresses."

Brown, K.J. and R.J. Hebda. 2002. Ancient fires on southern Vancouver Island, British Columbia, Canada: a change in causal mechanisms at about 2,000 ybp. Environ. Archaeol. 7:1–12. www.ingentaconnect.com/content/maney/env/2002/00000007/00000001/art00001

"Charcoal records were examined from seven sediment cores and two stratigraphic sections on southern Vancouver Island, Canada. Charcoal influx and climate trend regressions were established using high order polynomial functions. During the late-glacial (ca. 13,000–10,000 ybp), variations in the charcoal record suggest that fires likely responded to changes in fuel availability and climate. The high incidence of early-Holocene (ca. 10,000–7,000 ybp) fires may have been partly modified by human activity, though it seems more likely that climate exerted the greatest control. A decrease in fires during the mid- and early late-Holocene from 7,000–4,000 and 4,000–2,000 ybp respectively is consistent with a regional moistening trend, implying that fires were climatically limited. In the late late-Holocene from 2000 ybp–present, several sites record an increase in charcoal influx even though climate was continuing to moisten and cool, suggesting that non-climatic factors were responsible for the observed increase in fire activity. Estimates of native populations range up to thousands of people for southern Vancouver Island before the arrival of Europeans. These people were knowledgeable of fire, suggesting that humans were responsible for the increase in fires during the late late-Holocene cool, moist interval."

Brown, K.J. and R.J. Hebda. 2002. Origin, development, and dynamics of coastal temperate conifer rainforests of southern Vancouver Island, Canada. Can. J. For. Res. 32(2):353–372.
www.nrcresearchpress.com/doi/abs/10.1139/x01-197

"Pollen and charcoal from East Sooke Fen, Pixie Lake, and Whyac Lake were used to reconstruct the postglacial vegetation, climate, and fire-disturbance history across a precipitation gradient on southern Vancouver Island, British Columbia. An open *Pinus* woodland covered the landscape in the early late-glacial interval. Fires were absent under a cool and dry climate. Closed mixed conifer forests of *Pinus, Picea, Abies, Tsuga heterophylla* (Raf.) Sarg., and *Tsuga mertensiana* (Bong.) Carrière replaced the *Pinus* biogeochron in the late late-glacial interval. Fires became more common even though climate was cool and moist. Open *Pseudotsuga menziesii* (Mirb.) Franco forests expanded westward during the warm dry early Holocene, though closed *Picea* and *Tsuga heterophylla* forests grew in the wettest part of the area at Whyac Lake. Modern precipitation gradients likely originated at this time. Fires occurred in forested ecosystems, although East Sooke Fen at the driest end of the gradient experienced less fire. The middle and late Holocene was characterized by increasing precipitation and decreasing temperature, respectively. *Quercus garryana* Dougl. stands spread westward during the mid-Holocene. Extant closed *Tsuga heterophylla* and Cupressaceae (*Thuja plicata* Donn. ex D. Don) forests arose in the wetter part of the gradient, whereas *Pseudotsuga* forests occupied drier eastern areas. During this interval, fires were rare in wet western regions but apparently more common in dry eastern regions."

Daniels, L.D. 1994. Structure and regeneration of old-growth *Thuja plicata* stands near Vancouver, British Columbia. MSc thesis. Univ. British Columbia, Dep. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/5160

"In many old-growth stands on submontane (elevation < ca. 600 m) sites in the Very Wet Maritime Coastal Western Hemlock biogeoclimatic subzone, *Thuja plicata* populations are considered to be declining. *Thuja* dominate the upper canopy of such stands, but are scarce or absent in the lower canopies and understories, and are believed to be in the process of being replaced by the more numerous *Tsuga heterophylla* and *Abies amabilis*. To assess *Thuja* population dynamics and to test the null hypothesis that *Thuja* populations are not sustained in old-growth forests, this study analyzed the structure of eight old-growth stands located near Vancouver, British Columbia, in which *Thuja*, *Tsuga* and *Abies* form the tree layer.

The effect of stand-level fire disturbances were evident in the composition, age, and size structures of three of the study stands. However, small-scale processes, indicative of the old-growth stage of stand development, dominated the dynamics of seven of the stands. Regardless of stand histories, *Thuja* populations included trees of a range of sizes and ages and there were individuals in the understories in all study stands, indicating that the species is capable of regeneration in old-growth forests. Size and age structure analysis revealed that regeneration of *Thuja* was sporadic and is hypothesized to be disturbance-related, whereas regeneration of *Tsuga* and *Abies* appears to have been continuous."

Daniels, L.D. 2003. Western redcedar population dynamics in old-growth forests: contrasting ecological paradigms using tree rings. For. Chron. 79(3):517–530.
http://pubs.cif-ifc.org/doi/abs/10.5558/tfc79517-3

"In coastal British Columbia, late-successional forests dominated by western redcedar (*Thuja plicata* Donn ex D. Don) are structurally complex, with deep multi-layered canopies, large trees that are > 250 years old, and abundant coarse woody debris (CWD). These forests are presumed to be 'old-growth' forests in which fine-scale gaps are the dominant disturbance regime, accounting for their structural diversity. In this study, I have used tree-ring analyses to investigate western redcedar regeneration dynamics in these old-growth forests. Western redcedar dominates canopies of many stands, but is rare in the understorey although it tolerates shade. The traditional interpretation is that western redcedar depends on catastrophic disturbance to regenerate and that it is replaced through succession by western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Pacific silver fir (*Abies amabilis* (Dougl. ex Loud.) Dougl. ex J. Forbes), which are abundant in the understorey. Dominant trees are perceived to represent an even-aged, post-disturbance cohort and the lack of regeneration indicates a population decline in the absence of catastrophic disturbances. In this paper, I investigate four assumptions underlying this interpretation: (1) Tree size indicates age. (2) Populations establish as even-aged, post-disturbance cohorts. (3) Abundant CWD represents recent mortality. (4) Regeneration is insufficient to maintain canopy dominance. Using tree-ring evidence, I show that population dynamics of western redcedar are a combination of gap-phase establishment and a continuous mode of recruitment from the subcanopy to the canopy. Specifically, size is a poor surrogate for tree age. Age distributions from 15 sites revealed uneven-aged populations, rather than single post-disturbance cohorts. Both logs and snags of western redcedar may persist more than 270 years; they do not represent recent mortality that is disproportionate to the number of live western redcedar in canopy. The regeneration niches of western redcedar and western hemlock overlap. For both species, gap-phase disturbances result in substrate suitable for successful seedling establishment. Preliminary results from dendroecological analysis of radial growth rates of trees in the subcanopy and canopy strata suggest that western hemlock and Pacific silver fir depend on gaps to recruit to the upper canopy, but recruitment of western redcedar may be independent of canopy gaps. I propose that differences in mode of recruitment to the canopy may explain the differences in population structures between western redcedar, western hemlock, and Pacific silver fir in the old-growth forest. These results provide an ecological precedent for use of a range of silvicultural systems, including clearcuts through single-tree harvesting and protection forests, when managing western redcedar in coastal British Columbia."

Daniels, L.D. and R.W. Gray. 2006. Disturbance regimes in coastal British Columbia. BC J. Ecosystems Manag. 7(2):44–56.
http://jem.forrex.org/index.php/jem/article/view/542

"What is the dominant disturbance regime in coastal British Columbia? In this literature review, we discuss the relative importance of fire versus canopy gaps as agents of disturbance affecting the structure and dynamics of unmanaged coastal forests in British Columbia. Our analyses focus on the province's wet coastal temperate rain forests, specifically the Hypermaritime and Very Wet Maritime Coastal Western Hemlock (CWHvh and CWHvm) subzones, and the Wet Hypermaritime and Moist Maritime Mountain Hemlock (MHwh and MHmm) subzones. After reviewing the relationships between disturbance events, disturbance regimes, and stand dynamics, we critically assess the traditional classification of fire regimes in the wet coastal temperate rain forests, in part by differentiating between fire occurrence and mean return intervals. We provide four lines of evidence to reject the traditional view that stand-initiating fire at intervals of 250–350 years was the dominant disturbance regime in the wet coastal temperate rain forests of British Columbia. According to recent field research, historical fires were very infrequent in wet coastal temperate rain forests and were more likely low- and mixed-severity events, rather than stand-initiating fires. As an alternative to fire, we propose that fine-scale gap dynamics is the dominant process explaining the structure and dynamics of most unmanaged stands in the province's wet coastal temperate rain forests. Improved understanding of the spatial and temporal attributes of disturbance regimes in coastal forests has important implications for sustainable forest management and conservation of biodiversity."

Daniels, L.D., P.L. Marshall, R.E. Carter, and K. Klinka. 1995. Age structure of *Thuja plicata* in the tree layer of old-growth stands near Vancouver, British Columbia. N.W. Sci. 69(3):175–183.
www.vetmed.wsu.edu/org_NWS/NWSci%20journal%20articles/1995%20files/Issue%203/v69%20p175%20Daniels%20et%20al.pdf

"Age and diameter data were collected from 720 sound stumps (diameter ≥ 7.5 cm) of *Thuja plicata* (western redcedar) trees from 15 old-growth submontane cutover sites, within three watersheds near Vancouver, B.C. The relationship between age and DBH was quantified by regression analysis. The age structure on different sites was compared using age frequency distribution.

Regression models revealed weak, but still significant, relationships between age and diameter at breast height. Age distribution curves showed that the *Thuja* stands had been uneven-aged. The predominance of peak age classes indicated that establishment had been episodic and the populations were not in demographic equilibrium. We hypothesize that wind and fire disturbances and long-term climatic variation influenced the population dynamics and can explain the peaks observed in the age structures. Within the study area, *Thuja* populations are probably in a continual state of disequilibrium."

Day, W.R. 1957. Sitka spruce in British Columbia—a study in forest relationships. For. Commission Bull. No. 28. Her Majesty's Stationery Off., London, England.

Charcoal below the humus layer at a site above Skidegate on Haida Gwaii indicated that there had been a fire in the mid-1800s. Charcoal at depths of 70–120 cm in the soil profile provided evidence of much older fire activity and subsequent erosion. Near Queen Charlotte City, charcoal was also found at the surface, and the remains of a burned soil surface were located at 95 cm depth. Additional charcoal was found deeper still, in a layer of glacial till that began at a depth of 132 cm. Other sites with charcoal in the soil profile were near the Yakoun River, Mamin River, Gold Creek, Juskatla Inlet, Port Clements, and Tlell. Most were hillsides; some were alluvial flats. "The very ancient date of some of the fires from which this charcoal originated is sufficient to show that periodically and independently of anything that modern man may have done, the forest in these regions has been liable to be burned." Charcoal was also found at sites near Lakelse, Terrace, and Kitsumkalum.

Dorner, B. and C. Wong. 2003. Natural disturbance dynamics in coastal British Columbia. Coast Information Team, Victoria, B.C. www.citbc.org/b-NatDist-DornerWong-May03.pdf

"Natural disturbances, along with the activities of First Nations peoples, have historically shaped the composition and structure of forests on the coastal landscape. Natural disturbances can impact timber production by damaging or killing trees, but they are also agents of diversity and renewal that ensure a steady supply of important habitat elements such as snags, fallen trees, and browsing opportunities for many species. A good understanding of natural disturbance dynamics is thus an important first step towards maintaining a sustained timber supply, as well as sustaining ecosystem function and habitat characteristics to which native species have adapted. This report provides background information on natural disturbance regimes and identifies forest management issues arising from our understanding of natural forest dynamics in Haida Gwaii, the North and Central Coast, and northern Vancouver Island.

The landscape in the area is varied, consisting of lowlands, intricate coastlines, extensive floodplains, and coastal mountain ranges with deeply incised valleys and steep-sided fjords. The moist, cool climate, along with physiographic and topographic characteristics, are influential drivers of forest pattern and disturbance dynamics. In the low-lying coastal sections and exposed slopes near the outer coast, patches of productive forest often occur within a matrix of non-forested bog lands and stunted bog woodland. In the watersheds of the insular and mainland mountain ranges, the forest mosaic typically consists of large, continuous tracts of all-aged, structurally diverse old-growth coastal western hemlock (CWH) forest, separated by cliffs, gullies, wetlands, and shrub-covered avalanche and landslide tracks.

Over the majority of the coastal landscape, stand-replacing disturbances are rare and stands are very old. Death and reestablishment of trees primarily occurs in small canopy gaps of ten trees or fewer. These gaps are typically created by a combination of wind and pathogens, and make up around 10 to 30 percent of the area in old-growth stands. Geomorphic disturbances are the most important naturally occurring high-severity, stand-replacing events in the area. Wind and fire may also occasionally create larger canopy openings, but return intervals for these larger events are on the scale of millennia throughout the majority of the area. Flooding is a key element of forest dynamics in floodplains and estuaries. Other agents that may occasionally injure or kill trees include snow, ice, frost, and drought, as well as insects and mammals, most notably porcupines, beavers, and deer. The different types of disturbances do not occur homogeneously across the forest landscape. Rather, most of the agents are confined to, or occur predominantly in specific stand types and on specific site types or landscape positions."

Dorner, B. and C. Wong. 2003. Natural disturbance dynamics on the North Coast. North Coast LRMP background report. Victoria, B.C. http://archive.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/ncoast/docs/reports/background/Natural_Disturbance_finalDec162002.pdf

"Natural disturbances, along with the activities of First Nations peoples, have historically shaped the composition and structure of forests on the North Coast. Natural disturbances can impact timber production by damaging or killing trees, but they are also agents of diversity and renewal that ensure a steady supply of important habitat elements such as snags, fallen trees, and browsing opportunities for many species. A good understanding of natural disturbance dynamics is an important first step towards achieving forest management goals such as sustained timber supply and the maintenance of habitat characteristics to which native species have adapted. This report provides background information to the North Coast LRMP Table on natural disturbance regimes and identifies forest management issues arising from our understanding of natural forest dynamics in the plan area.

The moist, cool climate strongly influences forest dynamics on the North Coast. The landscape in the plan area is varied, consisting of lowlands, intricate coastlines, extensive floodplains, coastal mountains and steep sided fjords. These physiographic and topographic characteristics are also influential drivers of disturbance dynamics in the area. In the watersheds of the coastal mountain ranges, the forest mosaic typically consists of large, continuous tracts of all-aged, structurally diverse old-growth coastal western hemlock (CWH) forest, separated by cliffs, gullies, wetlands, and shrub-covered avalanche and landslide tracks. In the low-lying coastal sections, patches of productive forest occur within a matrix of non-forested bog lands and stunted bog woodland.

Over the majority of the North Coast landscape, small canopy gaps of ten trees or less, caused primarily by wind or pathogens are the primary mode of disturbance. Geomorphic disturbances can play an important role in susceptible parts of the landscape and are the main naturally occurring high-severity, stand-replacing events in the area, although wind and fire may also occasionally create larger canopy openings. Flooding is a key element of forest dynamics in floodplains and estuaries. Other agents that may occasionally injure or kill trees include frost and drought, insects, and mammals, most notably porcupines, beavers, and deer. The different types of disturbances do not occur homogeneously across the forest landscape. Rather, many of the agents are confined to, or occur predominantly in specific stand types and on specific site types or landscape positions."

Eis, S. 1962. Statistical analysis of several methods for estimation of forest habitats and tree growth near Vancouver, B.C. Univ. British Columbia, Fac. For., Vancouver, B.C. Fac. For. Bull. No. 4.

The author examined many climatic and environmental factors in forests of the south coast in order to evaluate plant community and forest productivity relationships. Most of his study plots contained "tree layers of almost uniform age." Douglas-fir stands commonly exhibited this uniformly aged upper canopy and likely originated after fire. In the absence of disturbance, it was noted that the more shade-tolerant tree species would come to dominate these sites. Fire years were as follows—University of British Columbia Malcolm Knapp Research Forest: 1550, 1660, 1770, 1780, 1800, 1830, 1840, 1868; Coquitlam River: 1540, 1690, 1790, 1860, 1890; Vancouver: 1840, 1880; and Mount Seymour: 1690, 1840, 1890, 1900.

Faculty of Forestry. 1953. University Forest management plan. Univ. British Columbia, Fac. For., Vancouver, B.C.

Fires burned over portions of the Malcolm Knapp Research Forest near Maple Ridge in 1780, 1840, 1868, 1925, 1926, 1931, and 1949. The 1868 wildfire was the most extensive and burned most of the western half of the Research Forest.

Gavin, D.G. 2000. Holocene fire history of a coastal temperate rain forest, Vancouver Island, British Columbia, Canada. PhD thesis. Univ. Washington, College For. Resourc., Seattle, Wash.
https://digital.lib.washington.edu/researchworks/handle/1773/5477

"The current lack of information about the temporal and landscape pattern of fires is a key source of uncertainty about natural disturbance regimes in coastal temperate rain forests. Two approaches were employed to examine fire history within a 700 ha low elevation area on the west coast of Vancouver Island: (1) point estimates of time-since-fire from tree ages and radiocarbon dates on soil charcoal, and (2) spatially aggregated estimates of fire occurrence from an 1800-year lake sediment record of charcoal accumulation. To aid with the first approach, the accuracy of the radiocarbon method for dating known fire events was evaluated. It was found that calibrated radiocarbon ages of soil charcoal consistently overestimated fire ages by 100–400 years due to the age of wood at the time of the fire. Estimates of time-since-fire at 83 sites ranged from 64 to ca. 12,220 cal. years before present. Approximately 20% of the sites have not burned for over 6000 years; these are on low fire-susceptibility landforms (i.e., north aspects and low terraces), which burned mainly in the early Holocene. In contrast, all sites on high-susceptibility landforms (i.e., south aspects) burned within the last 800 years. In the second approach, distinct peaks in charcoal in the lake sediment record corresponded with fires within 250 m of the lake. Fire intervals in this area increased from ca. 50 years (AD 200–900) to ca. 350 years (AD 1100–present), corresponding with regional climatic change. The decadal-scale fire frequency detected in the lake sediment record contrasts with the > 2000-year time-since-fire detected in a large area near the lake. Interpreted together, these records suggest that fires repeatedly burn certain sites. Fire frequency on high-susceptibility landforms was probably sufficient during the late Holocene to support Douglas-fir, a species dependent on fire for regeneration. On low-susceptibility landforms, extremely low fire frequency probably allowed late-successional forest structure to persist throughout the late Holocene. The extremely long time-since-fire detected in a large portion of the study area supports the distinction of the coastal temperate rain forest as affected by a fundamentally different fire history than forests further inland."

Gavin, D.G., L.B. Brubaker, and K.P. Lertzman. 2003. An 1800-year record of the spatial and temporal distribution of fire from the west coast of Vancouver Island, Canada. Can. J. For. Res. 33(4):573–586.
www.nrcresearchpress.com/doi/abs/10.1139/X02-196

"Charcoal records from lake sediments may show changes in fire frequency over thousands of years, but such records are ambiguous with regard to the actual locations of fires. Using a comparison of fire dates from an 1800-year lake sediment record from the west coast of Vancouver Island (British Columbia, Canada) and dates of last fire from 38 sites in the same watershed using tree-ring and soil-charcoal ^{14}C dates, we estimated the source area that contributes to charcoal peaks and determined the degree to which fires were biased to certain locations. Twenty-three charcoal peaks, likely corresponding with individual fire events, were objectively identified from the sediment record. Comparison of fire dates from charcoal peaks in the sediment record with fire dates from points near the lake suggests that the charcoal source area is within 500 m of the lake edge. Fire occurrence within this charcoal source area decreased sharply at AD 1100 from ca. 50 to ca. 300 years between charcoal peaks, coeval with the first 'Little Ice Age' cooling. Soil-charcoal radiocarbon dates revealed that 37% of the charcoal source area had not burned over the last 1800 years and that the 23 fires identified in the sediment record were restricted to south-facing slopes near the lake. This spatial pattern may result only if fire is >25 times more likely to occur on susceptible sites (south-facing slopes) than on less susceptible sites. This strong bias in fire location ensured the millennial-scale persistence of large areas of late successional forest through past climatic periods."

Gavin, D.G., L.B. Brubaker, and K.P. Lertzman. 2003. Holocene fire history of a coastal temperate rain forest based on soil charcoal radiocarbon dates. Ecology 84(1):186–201.
http://dx.doi.org/10.1890/0012-9658(2003)084%5B0186:HFHOAC%5D2.0.CO;2

"The long-term role of fire in coastal temperate rain forest is poorly understood. To determine the historical role of fire on western Vancouver Island (British Columbia, Canada), we constructed a long-term spatially explicit fire history and examined the spatial and temporal distribution of fire during the Holocene. Two fire-history parameters (time-since-fire [TSF] and fire extent) were related to three landscape parameters (landform [hill slope or terrace], aspect, and forest composition) at 83 sites in a 730-ha low-elevation (less than ~200 m) area of a mountainous watershed. We dated fires using tree rings (18 sites) and 120 soil-charcoal radiocarbon dates (65 sites). Comparisons among multiple radiocarbon dates indicated a high probability that the charcoal dated at each site represented the most recent fire, though we expect greater error in TSF estimates at sites where charcoal was very old (>6000 yr) and was restricted to mineral soil horizons. TSF estimates ranged from 64 to ~12220 yr; 45% of the sites have burned in the last 1000 yr, whereas 20% of the sites have not burned for over 6000 yr. Differences in median TSF were more significant between landform types or across aspects than among forest types. Median TSF was significantly greater on terraces (4410 yr) than on hill slopes (740 yr). On hill slopes, all south-facing and southwest-facing sites have burned within the last 1000 yr compared to only 27% of north- and east-facing sites burning over the same period. Comparison of fire dates among neighboring sites indicated that fires rarely extended >250 m. During the late Holocene, landform controls have been strong, resulting in the bias of fires to south-facing hillslopes and thus allowing late-successional forest structure to persist for thousands of years in a large portion of the watershed. In contrast, the early Holocene regional climate and forest composition likely resulted in larger landscape fires that were not strongly controlled by landform factors. The millennial-scale TSF detected in this study supports the distinction of coastal temperate rain forest as being under a fundamentally different disturbance regime than other Pacific Northwest forests to the east and south."

Green, R.N., B.A. Blackwell, K. Klinka, and J. Dobry. 1999. Partial reconstruction of fire history in the Capilano watershed. In: Analysis reports, watershed management plan # 5. [CD-ROM]. Greater Vancouver Regional Distr., GVRD Watershed Ecol. Inventory Program.

"Catastrophic fires have historically burned at infrequent intervals in the Capilano Watershed. These fires were not restricted to this watershed, but were part of regional-level episodes of intense fire activity that affected coastal BC and Washington state. The distribution and frequency of fires identified in other fire history studies undertaken in these areas were consistent with those found in the Capilano study. Conditions associated with these fires are believed to involve unusual synoptic weather patterns featuring long periods of drought (months and/or years preceding fires), higher lightning frequency, and unusual wind patterns.

The area of fire episodes identified in this project represent a partial reconstruction based on visible evidence, primarily the presence of Douglas-fir which commonly regenerates following fire. The young fire-origin stands studied in detail represented fires that burned in the late 1800s and the 1920s. These stands generally established with an initial regeneration pulse of 16–25 years, with sporadic recruitment occurring up to 40–60 years after disturbance. In addition to Douglas-fir, western hemlock and redcedar also formed significant stand components, indicating all three can function as early seral species following fire.

Post-settlement fires were found to occur fairly regularly from about 1855. The period of greatest fire frequency occurred in the 1920s to early 1930s during the period of extensive railway logging. Presettlement fire episodes occurred in nearly every century from about 1200 AD. Evidence of the oldest fire-origin stand dated back to 797 AD. The majority of these fire episodes coincided with fires identified in other studies throughout the south coastal region. Given the limitations of accurately dating fire disturbance in these older coastal forests, the fire episode dates can only be considered approximate.

Fragments of fire-origin stands were distributed throughout the watershed area. The majority occurred on warm aspect slopes in the CWH zone. The MFRI for these forests was estimated to be approximately 350 years based on multi-cohort fire-origin stands found in the study area. It is expected that forests occurring on cooler, moister sites will have longer MFRI's.

This partial reconstruction of fire history in the Capilano Watershed indicates fire has been a significant disturbance agent in these forests for the past 1000 years. This is consistent with other coastal fire history studies undertaken as early as 1915. Clearly, the potential for catastrophic fire is real, and fire hazard and risk must be incorporated into long-term land management planning."

Green, R.N. and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 28.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh28.htm

"The CWHmm1 is mainly restricted to Vancouver Island where it occurs along the leeward side of the Vancouver Island Ranges above the CWHxm subzone. It also occurs at higher elevations on Quadra, Sonora, and West and East Thurlow islands. It has a discontinuous distribution, often occurring in the upper portions of valleys draining the eastern slopes of the Vancouver Island Ranges. Elevational limits range from approximately 450 to 700 m (above the CWHxm if present), although it extends lower in isolated cases." "It has moist, mild winters and cool but relatively dry summers. Historically, dry summers have occasionally resulted in stand-replacing wildfires, which have contributed to the abundance of Fd [Douglas-fir] in this variant."

"The CWHmm2 occurs at higher elevations along the leeward side of the Vancouver Island Ranges, below the MH zone. Elevational limits range from approximately 700 to 1100 m." "Like the submontane variant, the CWHmm2 has a growing season water deficit from the rainshadow effect of the Vancouver Island mountains." "A history of wildfires has contributed to the relatively large stand component of Fd throughout the CWHmm2."

"The CWHms1 occurs at higher elevations in drainages of the upper Fraser River east and north of Chilliwack, and in the eastern portion of the Coast Mountains from upper Harrison Lake to the Homathko River. Elevational limits range from approximately 650 to 1200 m in submaritime areas, and from 900 to 1350 m in subcontinental areas further to the east." "The CWHms1 has a climate transitional between the coast and interior, characterized by moist, cool winters, and cool but relatively dry summers. Historically, dry summers have resulted in stand-replacing wildfires, which have contributed to the abundance of Fd in this variant."

"The CWHms2 occurs at lower elevations in submaritime and subcontinental areas north of the head of Knight Inlet. Its major occurrences include the lower Kimsquit River, southern Dean Channel, Labouchere Channel, South Bentinck Arm, and the main rivers draining into the east end of Owikeno Lake. Elevational limits range from sea level to approximately 700 m." "The CWHms2 has a climate transitional between the coast and interior, characterized by moist, cool winters and cool but relatively dry summers. Historically, dry summers have resulted in stand-replacing wildfires, which have contributed to the abundance of Fd in this variant."

Hebda, R.J., K. Gustavson, K. Golinski, and A.M. Calder. 2000. Burns Bog ecosystem review—synthesis report for Burns Bog, Fraser River Delta, south-western British Columbia, Canada. Environ. Assess. Off., Victoria, B.C.
http://a100.gov.bc.ca/appsdata/epic/documents/p60/1036434231789_16af42884ae64e0f8553d621be48be92.pdf

"Fires disturbed Burns Bog many times in the past and played a role in the natural dynamics of *Sphagnum* communities. First Nations may have used fire to increase cranberry yields. In recent decades, human-caused fires have burned widely in the study area. In the last decade, 136.2 ha, or 4.6% of the Bog burned during three widely-distributed fires."

"Fire has been an element of the Burns Bog ecosystem for a long time and has been suggested as one of the drivers of hummock-hollow processes. Prior to European settlement, fires in Burns Bog likely affected small discontinuous patches in a largely wet landscape. This pattern would have met the criteria of a steady-state (sustainable) ecosystem mosaic. Basically, fires were not likely a threat to the ecosystem because the Bog was large and relatively wet."

Howe, C.D. 1915. The reproduction of commercial species in the southern coastal forests of British Columbia. In: Forest protection in Canada 1913–1914. Committee on Forests, Commission of Conservation, Canada. Ottawa, Ont, pp. 212–230.
www.biodiversitylibrary.org/bibliography/51177#/summary

This study was conducted in 1914 and concerned the regeneration and survival of Douglas-fir after logging and slashburning. Important aspects were the periodicity of fires and distance from tree seed sources. The study sites were at Shawnigan Lake, Cowichan Lake, Chemainus, Union Bay, Burrard Inlet, Gibsons, and Powell River. Fire years were as follows—Shawnigan Lake: 1598, 1743, 1789, 1813, 1843; Cowichan Lake: 1488, 1598, 1684, 1743, 1789; Chemainus: 1373, 1598, 1743, 1789, 1813, 1843; Union Bay: 1453, 1598, 1743, 1789, 1813, 1843; Burrard Inlet: 1598, 1743, 1789, 1813, 1843; Gibsons: 1488, 1598, 1684, 1743, 1789, 1813, 1843; and Powell River: 1557, 1598, 1743, 1789, 1813, 1843. The author concluded that the frequency of widespread fires was every 86 years between 1554 and 1814, 27 years between 1814 and 1894, and 5 years between 1894 and 1914.

Keenan, R.J. 1993. Structure and function of western red cedar and western hemlock forests on northern Vancouver Island. PhD thesis. Univ. British Columbia, Dep. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/2178

"Two forest types predominate on middle or upper-slope situations on northern Vancouver Island: an old-growth type dominated by western red cedar (*Thuja plicata* Donn) and western hemlock (*Tsuga heterophylla* (Raf.) Sarge) (the CH type), and a windstorm-derived, second-growth type dominated by western hemlock and amabilis fir (*Abies amabilis* (Dougl.) Forbes) that largely originated following a widespread windstorm in 1906 (the HA type). Distribution of the two types has no obvious relationship with geology, topography or mineral soil."

"The diameter-class structure of the CH type suggested it was a self-replacing, climax community. The diameter-distribution of western hemlock indicated continuous recruitment, while that of western red cedar suggested more periodic recruitment, at a slower rate than hemlock. The diameter class distribution of the HA type was unimodal, suggesting an even-aged stand, but a sample of tree ages indicated that many trees established some time before, or after, the 1906 windstorm."

Lertzman, K. 2000. Long-term fire histories in a coastal temperate rainforest. For. Renewal BC, Res. Program. Simon Fraser Univ., School Resourc. Environ. Manag., Burnaby, B.C.
www.for.gov.bc.ca/hfd/library/frbc2000/frbc2000mr35.pdf

"The scarcity of stand-structural evidence of fire is a distinctive feature of the wetter coastal forests of British Columbia. Age-class data indicates that it has been many hundreds of years since the most recent fire in many areas, but stand origin dates are rarely available and fire may have been more common during earlier climatic periods. We employed two approaches to reconstruct fire history in a remote watershed on Vancouver Island: 1) point estimates of time-since-fire (TSF) from tree ages and radiocarbon dates on soil charcoal within a 700 ha low elevation area, and 2) spatially aggregated estimates of fire occurrence from an 1800-year lake sediment record of charcoal within the study area.

For a grid of 83 terrestrial sites, time-since-fire ranged from 1886 AD (64 years before present) to 12220 cal. years before present. Overall, hillslope sites had a significantly shorter median TSF than terrace sites (740 and 4410 years, respectively). The TSF distribution indicated that ca. 20% of the sites have not burned in 6000 years. These areas occur mainly on terraces or north-facing hillslopes that receive little direct solar radiation. Warm and dry summers during the early Holocene were probably necessary to overcome these site-level controls. 35% of the sites have burned in the last 600 years. The areas occur mainly on south-facing hillslopes, and usually contain a seral stand of Douglas-fir and in some locations an association of stunted western redcedar and dense shrub layer of salal. Recurrent fire on these sites was necessary to maintain Douglas-fir in the stand, and possibly contributed to the lower productivity of these sites. Fire intervals were detected at only 16 sites, which showed similar trends to TSF. Fire extent was very limited, rarely extending beyond 250 m.

The lake sediment record suggests fire intervals within a 250 ha area increased sharply at 1100 AD from decadal to centennial scales, coincident with a shift to cooler/wetter conditions found elsewhere in western North America. Comparison of the lake sediment record with the soil charcoal records near the lake provided evidence that fires were spatially restricted and burned the same areas repeatedly. These results suggest that topographic influences on fire susceptibility ensure that large areas do not burn during periods of higher fire frequency. This study significantly increases our knowledge regarding the spatial extent and long-term frequency of fire in coastal British Columbia."

Lertzman, K., D. Gavin, D. Hallett, L. Brubaker, D. Lepofsky, and R. Mathewes. 2002. Long-term fire regime estimated from soil charcoal in coastal temperate rainforests. Conserv. Ecol. 6(2):5. www.consecol.org/vol6/iss2/art5

"Coastal temperate rainforests from southeast Alaska through to southern Oregon are ecologically distinct from forests of neighboring regions, which have a drier, or more continental, climate and disturbance regimes dominated by fires. The long-term role of fire remains one of the key outstanding sources of uncertainty in the historical dynamics of the wetter and less seasonal forests that dominate the northerly two-thirds of the rainforest region in British Columbia and Alaska. Here, we describe the long-term fire regime in two forests on the south coast of British Columbia by means of 244 AMS radiocarbon dates of charcoal buried in forest soils. In both forests, some sites have experienced no fire over the last 6000 years and many other sites have experienced only one or two fires during that time. Intervals between fires vary from a few centuries to several thousand years. In contrast to other conifer forests, this supports a model of forest dynamics where fires are of minor ecological importance. Instead, forest history is dominated by fine-scale processes of disturbance and recovery that maintain an ubiquitous late-successional character over the forest landscape. This has significant implications for ecosystem-based forest management and our understanding of carbon storage in forest soils."

Lertzman, K.P., G.D. Sutherland, A. Inselberg, and S.C. Saunders. 1996. Canopy gaps and the landscape mosaic in a coastal temperate rain forest. Ecology 77(4):1254–1270. http://dx.doi.org/10.2307/2265594

"We studied canopy gaps over a range of stand ages and site moisture classes in the temperate rain forest of Clayoquot Sound, southwestern British Columbia, Canada. We tested predictions about the landscape mosaic at three levels of resolution: the forest as a whole, gaps, and gapmakers. In addition to canopy gaps arising from the patchy mortality of dominant trees (developmental gaps), we described the prevalence and characteristics of gaps arising from edaphic and topographic features. Roughly 56% of the forest area is influenced to some degree by canopy openings (canopy gap + expanded gap), with 30% of forest area in canopy gaps averaged over all sites (14% developmental canopy gaps and 16% in edaphic canopy gaps). Within the most intensively sampled biogeoclimatic subzone, 73% of gaps were developmental in origin. The majority of edaphic gaps result from streamcourses. Though percent area in developmental canopy gaps was similar across stand age classes, gaps and gapmakers were more common in old growth than in mature stands.

Most developmental gaps resulted from the mortality of more than one tree: 96% of the developmental gaps had more than one gapmaker, and 50% had three or more. Mature stands had a significantly higher number of gapmakers per gap than old-growth stands. Old-growth forests were thus dominated by many small gaps and mature forests by fewer larger gaps. Drier and wetter sites had more gapmakers per gap than did stands on mesic sites. The number of decay classes of gapmakers in developmental gaps increases with number of gapmakers per gap, indicating that larger gaps represent the combined effects of distinct mortality events separated in time, rather than single large events. Gapmakers in developmental gaps were distributed broadly and evenly over the range of decay classes, suggesting a continuous pattern of recruitment of gapmakers rather than larger episodic mortality events. The snapping of boles and standing death were the most common modes of gapmaker mortality, together accounting for 76% of the mortality of gapmakers. Uprooting was the least common mode of gapmaker mortality in both mature and old-growth forests (23.6% and 15.6%, respectively; 20.6% of all gapmakers) and uprooting was more common in drier and wetter sites than in mesic sites.

These general trends in gap-phase structure and gap formation processes are consistent with data on gaps and forest age structure collected elsewhere on the British Columbia coast, suggesting that a regime of small-scale, low-intensity disturbance is common in the old-growth forests of coastal British Columbia. We estimate that, in the absence of large-scale disturbances, turnover time for this forest is between 350 and 950 yr, resulting in ubiquitous late successional character throughout the landscape mosaic. Silvicultural practices intended to emulate the natural disturbance regime of these forests should create small gaps of 3–10 trees in an otherwise continuous forest matrix and should retain substantial late-successional characteristics within managed forests."

McCloskey, S.P.J. 2007. Western hemlock looper: a biological agent of disturbance in coastal forests of British Columbia. PhD thesis. Univ. British Columbia, Dep. Geog., Vancouver, B.C. https://circle.ubc.ca/handle/2429/31425

"My dissertation examines western hemlock looper (*Lambdina fiscellaria lugubrosa* Hulst) as an agent of disturbance in coastal forests of British Columbia. Western hemlock looper populations along coastal British Columbia have undergone seven episodes of outbreak from 1911 to 2004, leading to visible defoliation of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)-dominated forests. My research investigates the causal factors that influence the timing of outbreaks, the impacts the resultant defoliation has on forest structure and composition, and the spatio-temporal dimensions of this biological disturbance agent.

In order to identify the specific antecedent climate conditions that contributed to western hemlock looper outbreaks between 1911 and 2003, I analyzed local meteorological records to develop a moisture stress index of combined temperature and precipitation data. This index included periods of warm, dry climate between 1895 and 2004, and I hypothesized that these warm, dry conditions would improve the survival of western hemlock looper larvae and facilitate population increases. Indeed, a high moisture stress index in June was associated with the onset of visible defoliation by western hemlock looper populations later that year. Furthermore, a high moisture stress index over the entire growing season (May to September) was associated with conditions two years before visible defoliation events, thereby providing a trigger for populations to increase to outbreak levels in subsequent years. Given predicted warmer and drier climatic conditions during the growing season in coastal British Columbia, I anticipate that the frequency of western hemlock looper outbreaks will increase in future."

"To determine if the frequency of western hemlock looper outbreaks changed over the past two centuries, I employed dendroentomological methods to reconstruct outbreaks that occurred on Coquitlam Island, a 75 ha island where three outbreaks had been documented during the 20th century. I used differential rates of tree-ring growth between 'host' western hemlock and 'non-host' western redcedar to detect periods of radial growth suppression associated with western hemlock looper outbreaks using the program OUTBREAK. I used known periods of western hemlock looper outbreaks in the 20th century to calibrate and verify the reconstruction techniques. I successfully reconstructed four outbreaks over a 135-year period between 1775 and 1910. The dendroentomological method was successful at identifying low, moderate and high severity outbreaks, whereas the written record identified only periods of visible defoliation from high severity outbreaks. Based on the reconstructed outbreaks, I have determined that the frequency of defoliations has not changed significantly over the past 200 years."

Parminter, J. 1983. Fire history and fire ecology in the Prince Rupert Forest Region. In: Prescribed fire–forest soils symposium proceedings. Mar. 2–3, 1982, Smithers, B.C. R.L. Trowbridge and A. Macadam (compilers and editors). B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Rep. 16, pp. 1–35.

www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Lmr016.htm

"Fire ecology knowledge is required for fire management operations as well as for other aspects of natural resource management. Natural fire has influenced ecosystem processes at various scales and has been a major factor in determining the composition and distribution of vegetation types. Different fire types and frequencies can be classed into fire regimes and these regimes related to the role of fire in different ecosystems.

Forest tree species and other vegetation possess varying degrees of fire tolerance and fire adaptations, or indeed may be totally dependent on fire for their continued existence. On the other hand certain vegetation species are fire sensitive and may be removed altogether or lessened in numbers by fire. It appears that fire has played a diverse role in the biogeoclimatic zones of the Prince Rupert Forest Region – from very rare in the Coastal – Cedars – Pine – Hemlock to very common in the Boreal White and Black Spruce. Post-fire vegetation development can follow one of several directions, the direction taken is determined by site characteristics, the nature of the fire, and subsequent environmental conditions.

Significant differences may exist between the natural fire regime and historical fire effects and the fire regime and fire effects imposed by man and his various land management activities. Guidance in the artificial application of fire can be obtained from a knowledge of the natural place of fire in the ecosystem in question."

Few lightning fires occurred on the North Coast between 1940 and 1982, and of 63 detected, only 11% were greater than 50 ha. The CCPH biogeoclimatic zone has little or no fire activity, while some portions of the CWH and MH, such as between Terrace and Kitimat and east of Bella Coola, have more lightning-caused fires than elsewhere. The absence of Douglas-fir in the wetter maritime CWH may be due to a much reduced fire frequency.

Parminter, J. 1991. Fire history and effects on vegetation in three biogeoclimatic zones of British Columbia. In: Fire and the environment: ecological and cultural perspectives. Proc. Int. Symp. Mar. 20–24, 1990, Knoxville, Tenn. S.C. Nodvin and A. Thomas (editors). U.S. Dep. Agric. For. Serv., Asheville, N.C. Gen. Tech. Rep. SE-69, pp. 263–272. www.srs.fs.usda.gov/pubs/gtr/gtr_se069/gtr_se069-section04.pdf

"The different fire regimes present in the province of British Columbia are well-illustrated by the Coastal Western Hemlock, Boreal White and Black Spruce, and Ponderosa Pine Biogeoclimatic Zones. Fires are variable in type, intensity, severity, effects, size, and interval. In the first two biogeoclimatic zones, stand replacement and/or partial stand replacement fires occur. Surface fires that maintain open forests with grassy understories are the historic norm in the Ponderosa Pine Zone.

Fire histories and fire effects have been determined for all three zones. In the Coastal Western Hemlock Zone the emphasis has been on fire history, stand establishment, and prescribed burning. Ecosystem-specific guides describing the type of fire suitable for silvicultural site preparation are widely available. Post-fire vegetation successional pathways have been developed for the Boreal White and Black Spruce Zone and are used to predict probable fire outcomes.

In recent times, the adverse implications of fire exclusion have been recognized in ecosystems such as those found in the Ponderosa Pine Zone. The reintroduction of fire through prescribed burning serves to address the problems and meet several resource management objectives."

Pearson, A.F. 2000. Natural disturbance patterns in a coastal temperate rain forest watershed, Clayoquot Sound, British Columbia. PhD thesis. Univ. Washington, College For. Resourc., Seattle, Wash.

"Disturbance patterns were investigated in a pristine old-growth 7000 ha watershed in Clayoquot Sound, British Columbia, Canada. The primary tools were an air photo record from 1939 – 1988, timber inventory data bases, and field measurements of stand structure. Disturbance patterns varied with location in the watershed and disturbance types were not of equal extent. The process domains of floodplains, hollows and hillslopes describe areas of similar geomorphic processes and so disturbance regimes, including different forest types and pattern of wind disturbance. On floodplain terraces (4% of the watershed), *Tsuga heterophylla* and *Abies amabilis* predominate (HA forest type). In hollows on colluvial slopes, (26% of the watershed), *Thuja plicata* and *Tsuga heterophylla* predominate (CH forest type). On bedrock hillslopes, (52% of the watershed), *Thuja plicata* and *Chamaecyparis nootkatensis* occur (scrub forest type). Historic geomorphic disturbances influenced 7% of the watershed, with debris flows and avalanches confined to the steep upper elevation slopes, landslides occurring primarily in hollows, and floods confined to a small riparian zone (2.4% of the watershed). Characteristics of old-growth forests were primarily influenced by process domains and species-specific interactions between wind and pathogens. *Abies* and *Tsuga* primarily die by snapping, likely due to their vulnerability to fungi that cause rot and weaken boles. *Thuja* on colluvial slopes die primarily by uprooting due to root abrasion on bedrock substrate from trees swaying in the wind, creating entry points for fungi. Disturbances were virtually all gap-phase events and do not appear to play a strong role in these forests. There were no stand-replacing wind disturbances in the study area within the past 140 years or any stand-replacing fires within the past 100 years. Geomorphic disturbances were stand-replacing but were confined to < 5% of the study area. If this pattern is a long-term phenomenon, then forest organisms are primarily adapted to small-scale disturbance events. Because nearly all forests in Clayoquot Sound are old (> 250 years), stand age is not a useful criterion for forest conservation. Process domains may be more useful for describing ecosystems, both for conservation purposes and as a basis for managing forests for natural variation."

Pearson, A.F. 2001. Patterns of wind disturbance in a coastal temperate rain forest watershed, Clayoquot Sound, British Columbia. In: Windthrow assessment and management in British Columbia. Proc. Windthrow Researchers Workshop. Jan. 31–Feb. 1, 2001, Richmond, B.C. S.J. Mitchell and J. Rodney (compilers), pp. 65–80.
www.for.gov.bc.ca/HFD/library/documents/windthrow.pdf

"Disturbance patterns were investigated in a pristine old-growth 7000 ha watershed in Clayoquot Sound, British Columbia, Canada. The primary tools were an air photo record from 1939 – 1988, timber inventory data bases, and field measurements of stand structure. The process domains of floodplains, hollows and hillslopes describe areas of similar geomorphic processes and so disturbance regimes, including different forest types and patterns of wind disturbance. On floodplain terraces (4% of the watershed), *Tsuga heterophylla* and *Abies amabilis* predominate (HA forest type). In hollows on colluvial slopes, (26% of the watershed), *Thuja plicata* and *Tsuga heterophylla* predominate (CH forest type). On bedrock hillslopes, (52% of the watershed), *Thuja plicata* and *Chamaecyparis nootkatensis* occur (scrub forest type). Characteristics of old-growth forests were primarily influenced by process domains and species-specific interactions between wind and pathogens. *Abies* and *Tsuga* primarily die by snapping, likely due to their vulnerability to fungi that cause rot and weaken boles. *Thuja* on colluvial slopes die primarily by uprooting due to root abrasion on bedrock substrate from trees swaying in the wind, creating entry points for fungi. Disturbances were virtually all gap-phase events and do not appear to play a strong role in these forests. There were no stand-replacing wind disturbances in the study area within the past 140 years. Geomorphic disturbances were stand-replacing but were confined to < 5% of the study area. If this pattern is a long-term phenomenon, then forest organisms are primarily adapted to small-scale disturbance events. Because nearly all forests in Clayoquot Sound are old (> 250 years), stand age is not a useful criterion for forest conservation. Process domains may be a more useful for describing ecosystems, both for conservation purposes and as a basis for managing forests for natural variation."

Pearson, A.F. 2010. Natural and logging disturbances in the temperate rain forests of the Central Coast, British Columbia. Can. J. For. Res. 40:(10)1970–1984.
www.nrcresearchpress.com/doi/abs/10.1139/x10-137

"Natural disturbances frame the spatial and temporal processes of ecosystems and are the foundation for ecosystem-based management. In the coastal temperate rain forests of British Columbia, landscape patterns of natural disturbances and their contrasts with logging are not well documented. Stand-replacing disturbances over the past 140 years were investigated for the Central Coast (1.5 million ha) at regional and local scales using a combination of aerial photograph interpretation and forest management GIS databases. At the regional scale, stand-replacing natural disturbances affected 3.1% of the forested area. The extent of natural disturbances was not strongly affected by the scale of analysis. In contrast, spatial pattern and scale were essential for discerning the full impact of logging. At the regional scale, logging affected 5.4% of the forested area. Within watersheds, however, logging occurred primarily in valley bottoms (81% ± 4%) with 59% ± 10% of valley bottom areas logged, 10 times the area of natural disturbances. Watershed size strongly affected riparian zones, with active floodplains comprising 53% ± 5% of valley bottom area in large (> 20 000 ha) watersheds. In physiographically diverse landscapes, geomorphic features (such as watersheds, valley bottoms, and fluvial landforms) are crucial for determining disturbance processes and effects of logging at ecologically relevant scales."

Pearson, W.J. 1968. A review and analysis of the fire history of the Queen Charlotte Islands. Report submitted to the Board of Examiners, Association of British Columbia Foresters, Vancouver, B.C. Unpubl. rep.

"About 250 years ago a major fire of undetermined size burned over a flat area of mature timber on the east side of the Mamin River near Juskatla." "About 110 years ago, an area of roughly 150,000 acres [60 700 ha] was burned in the largest fire known to have occurred on the Q.C.I." "About 1915, approximately 1,000 acres [404 ha] of mature timber on the east side of Yakoun Lake were destroyed by fire."

Pew, K.L. and C.P.S. Larsen. 2001. GIS analysis of spatial and temporal patterns of human-caused wildfires in the temperate rain forest of Vancouver Island, Canada. For. Ecol. Manag. 140(1):1–18.
www.sciencedirect.com/science/article/pii/S0378112700002711

"This study examines the spatial and temporal pattern of human-caused wildfires (HCWs) in the temperate rainforest of Vancouver Island (VI). A

Geographic Information System was used to locate HCWs that occurred on VI from 1950 through 1992, to divide VI into 1 km × 1 km grid cells, and to determine for each grid cell the climate and distances to various human-built infrastructures. Logistic regression was used to build a predictive model of the probability of HCW occurrence in each of the grid cells, using climate and distances as predictor variables. A total of 6329 wildfires occurred on VI over the 43 years study period, and 2747 of the grid cells contained at least one fire. The probability of a grid cell burning was positively correlated with summer temperature, and negatively correlated with precipitation and distances to municipalities, campgrounds, dirt roads, railroads and paved roads.

Grid cells were grouped into five classes of HCW probability: <20, 20–39, 40–59, 60–79, >80%. The lower the probability of HCW occurrence, the lower the number of fires per km^2 per year, the longer the fire cycle in years, and the larger the mean fire size. The unexpected larger mean fire size in areas with low HCW probability is due to logging fires being the most common type there, and logging fires being significantly larger than other types on all portions of VI. Where the HCW probability was highest, recreation and miscellaneous fires were most common, and these types of fires tended to be significantly smaller.

The annual number and annual area burned by HCWs on VI has been decreasing. These decreases have occurred primarily in the areas that have a high HCW probability, while increases have occurred where the HCW probability is low. These results indicate that HCWs are a significant part of the temperate rainforest ecosystem and that the spatial variation in their occurrence could be used to delimit fire management zones."

Pojar, J., K. Klinka, and D.A. Demarchi. 1991. Coastal western hemlock zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 95–111. www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap6.pdf

"Western hemlock, amabilis fir, western redcedar, Sitka spruce, and (especially with increasing elevation) yellow-cedar dominate the forests of the wetter maritime subzones, which cover the majority of the zone as a whole. Western hemlock and amabilis fir dominate the canopy of late seral stands. Windthrow plays an important role in the persistence of these species; relatively young and more or less even-aged stands are common as a result. Western redcedar stands typically occupy steep slopes or sites that regenerated following fire and/or have not been disturbed by windthrow for several centuries. Typical zonal stands are characterized by the Western hemlock – Amabilis fir – Alaskan blueberry association. This vegetation type features a well-developed shrub layer of ericaceous species (*Vaccinium alaskaense* [Alaskan blueberry], *V. parvifolium* [red huckleberry], *Gaultheria shallon* [salal]) and advance regeneration of western hemlock and amabilis fir, a poorly developed herb layer typified by *Blechnum spicant* (deer fern), and a well-developed moss layer dominated by *Rhytidiadelphus loreus*, *Hylocomium splendens*, and *Kindbergia oregana* (Oregon beaked moss)."

Price, K. and D. Daust. 2003. The frequency of stand-replacing natural disturbance in the CIT Area. Final rep. Coastal Inf. Team. www.citbc.org/b-DistFreq-PriceDaust-Oct03.pdf

"Ecosystem-based management often uses the landscape patterns arising from natural disturbance regimes to inform management. This report estimates the natural disturbance frequency and proportion of old forest in various portions of BC's north and central coast.

Using forest age, disturbance history and ecosystem classification, we divided the study area into units experiencing similar disturbance frequencies, estimated the frequency for each unit using three different techniques, and translated the range of variation in disturbance frequency into a historical range of old forest in each unit. We examined available datasets (Forest Inventory and small-scale Predictive Ecosystem Mapping) and selected the latter for analysis. We used an independent dataset to check and refine logging activity data. We filtered suspicious data in an attempt to create a reliable dataset. In particular, data beyond 120 years ago likely contained errors. We aged logged stands prior to analysis and assumed that all remaining young stands were caused by natural disturbance.

We examined the appropriateness of two broad-scale (biogeoclimatic variants and hydroriparian sub-regions) and two fine-scale (Analysis Units and biogeoclimatic site series groups) classification systems for defining disturbance units. Timber Analysis Units were inappropriate. Cluster analysis identified combinations of hydroriparian sub-regions and site series with homogeneous disturbance frequencies and variation in disturbance frequency over the past 120 years. Disturbance units defined included Hypermaritime, Outer Coast North, Outer Coast South and Inner Coast physiographic regions and upland, fluvial, ocean spray and avalanche track ecosystems within these regions. Alternatively, biogeoclimatic variants clustered into four groups.

The three estimation techniques provided similar estimates of the historical disturbance frequency experienced over the past 120 years for each disturbance unit. Disturbance frequency, and variation in disturbance frequency, increased with increasing distance from the coast. Within regions, upland ecosystems (excluding avalanche tracks) experienced less frequent disturbance (and less variable disturbance frequency) than fluvial or ocean spray ecosystems. Although the entire coast is dominated by old forest, estimates of the percent of forest over 250 years based on estimated disturbance frequencies for the past 120 years range from 46 – 73% in fluvial Inner Coast ecosystems to 95 – 99% in upland Hypermaritime ecosystems. These estimates can be used to inform management in the CIT area, but should be considered as hypotheses."

Schmidt, R.L. 1957. The silvics and plant geography of the genus *Abies* in the coastal forests of British Columbia. B.C. For. Serv., Victoria, B.C. Tech. Publ. T.46.

"In order to relate the incidence of fires to climate, it was necessary to obtain a picture of the extent and frequency of past forest fires. The even-aged character of fire-originated Douglas fir stands provides an opportunity to establish the dates of past forest fires, and by obtaining age samples of this species, a fairly comprehensive picture has been developed for Vancouver Island." "The most recent fire of gigantic proportions occurred about 300 years ago, when some 2,000,000 acres [809 000 ha] of forest was consumed on Vancouver Island. At that time fires also occurred in forests of the Mainland coast, but as yet their extent has not been established." Fire years for Vancouver Island were 130, 210, 300*, 350, 400*, 550, 620, 750, 860, 930, and between 1100 and 1200 years ago (*considered to have covered an extensive area).

Schmidt, R.L. 1970. A history of pre-settlement fires on Vancouver Island as determined from Douglas-fir ages. In: Tree-ring analysis with special reference to Northwest America: proceedings of a conference on biology of tree-ring formation, methods of measurement of tree rings, methods of analysis, and uses of tree-ring data. Feb. 19–20, 1970. J.H.G. Smith and J. Worrall (editors). Univ. British Columbia, Fac. For., Vancouver, B.C. Fac. For. Bull. No. 7, pp. 107–108.

The even-aged structure of old-growth coastal Douglas-fir stands indicates when historic fires occurred, most likely when periods of extended drought coincided with lightning storms. Evidence of fire is also present as charcoal in the soil and on the bark of live trees. The latter can persist for more than 400 years. Evidence indicated eight major fires occurred 150*, 230, 310*, 360, 410*, 560, 760, and 870 years ago (*considered to have covered an extensive area). Remnants of stands aged from 940 to 1300 years were found in many locales. Between 310 and 410 years ago, it is probable that more than 800 000 ha of forest burned on Vancouver Island. The Nimpkish Valley on northern Vancouver Island had eight major fires between 150 and 1100 years ago.

Toms, J.D. 1995. Age structure and stand dynamics of old-growth forests on Vancouver Island. MacMillan Bloedel Ltd., Land Use Planning Advisory Team, Nanaimo, B.C.

"During the summer of 1991, two exchange students from Germany, Rudiger Stoltz and Dirk Scheidemann, studied the age structure of old-growth forests on Vancouver Island. They aged stumps in 15 clearcut old-growth stands, and recorded ecological information from adjacent uncut stands. Stands in three areas of the island (Cowichan Division in the southeast, Kennedy Division in the west, and Kelsey and Menzies Bay Divisions in the northeast) and two biogeoclimatic zones (coastal western hemlock and coastal Douglas-fir zones) were sampled. However, their student thesis (Stoltz and Scheidemann 1992) analyzed only the age data. This report looks at the associated data, as well as at age structure.

Although the CWHmm2 typically contains a large component of Douglas-fir, it is present only in the most southern plots sampled in this study. Wildfires appear to be infrequent in the southern portion of the CWHmm2, and rare in the northern portion. Wildfires are also rare in the CWHvm. However, most of the sites in the CWHxm have experienced a major fire within the last 325 – 350 years. These fires may be associated with the last major burning period on the Olympic Peninsula in Washington State, or may represent the difference between the average interval of stand-destroying fires and the development of old-growth characteristics. These fires are necessary for Douglas-fir to remain as a dominant species in these stands; if fires do not occur, the forest will undergo succession and become a western hemlock dominated stand.

The periodic wildfires which occur in the CWHxm result in a relatively even-aged stand. In contrast, most stands in the CWHvm and CWHmm show no evidence of a major disturbance, and are regenerated through formation of small gaps. The result is uneven-aged stands with higher structural diversity and a more complex age structure than stands from the CWHxm."

Wright, T.G. 1955. Submission to the Royal Commission on forestry. Can. For. Products Ltd., Vancouver, B.C. Unpubl. rep.

The main stand of interest on northern Vancouver Island (80% Douglas-fir and 20% western hemlock and western redcedar) became established in about 1550 after a wildfire (estimated at 34 800 ha in extent) swept through the Nimpkish Valley from the Kilpala River at Nimpkish Lake upriver to Woss and Schoen Lakes, a distance of about 56 km. In addition, other fires—all considered to have been ignited by lightning after extended summer droughts—created large even-aged stands. These fires burned from the upper Oktwanch River northwest to the Davie River (in about 1400, and were partially re-burned by subsequent fires); south, east, and north of Vernon Lake and east and north of Woss Lake (in about 1685, totalling 13 700 ha); and along the Nimpkish River between Nimpkish and Woss Lakes (in about 1820, totalling 6800 ha). Remnant stands indicate that other fires occurred in 1200, 1320, and 1895.

ENGELMANN SPRUCE – SUBALPINE FIR BIOGEOCLIMATIC ZONE

Antos, J.A. and R. Parish. 2002. Dynamics of an old-growth, fire-initiated, subalpine forest in southern interior British Columbia: tree size, age, and spatial structure. Can. J. For. Res. 32(11):1935–1946. www.nrcresearchpress.com/doi/abs/10.1139/x02-116

"We used dendrochronological analysis of over 2000 trees in four 50 × 50 m plots to reconstruct the history and dynamics of a 330-year-old, fire-initiated spruce–fir forest. All lodgepole pine (*Pinus contorta* Dougl. ex Loud.), half of the canopy Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), but less than 10% of the canopy subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) dated from the first 50 years of stand development. Tree-ring patterns of individual surviving trees showed no evidence of disturbance during the first 200 years after stand initiation; subsequently, episodes of disturbance are indicated by periods of release in understory fir. Although many fir owe their canopy position to release after disturbance, few canopy fir in the current stand established in response to either the stand-initiating event or subsequent partial disturbances.

A seedling bank of long-lived fir appears critical to the dynamics of this forest. In contrast, establishment of almost all canopy spruce can be related to disturbance. This stand, although fire initiated, was structured primarily by a combination of partial disturbances and autogenic processes. We suspect that most old, fire-initiated stands in many forest regions are similarly structured and emphasize that the contribution of partial disturbances and autogenic processes should be fully assessed when examining their dynamics or managing such forests."

Antos, J.A. and R. Parish. 2002. Structure and dynamics of a nearly steady-state subalpine forest in south-central British Columbia, Canada. Oecologia 130(1):126–135.
www.springerlink.com/content/lct4cqyyqx5jhrk3/

"We examined the size, age, and spatial structure of trees in an old Engelmann spruce (*Picea engelmannii*)–subalpine fir (*Abies lasiocarpa*) forest based on four stem-mapped, 0.25 ha plots. Dendrochronological techniques were used on basal discs of 1,190 trees to reconstruct age and growth pattern, including dates of rapid growth increases. There were no obvious age cohorts or other evidence of past major disturbance. The abundance of both subalpine fir and spruce decreased rapidly with age, especially beyond the ages of 150 years. Very old trees were present, but rare. The best evidence from tree-ring width patterns for past disturbance was a period of release 100 years ago. However, few of the released trees grew into the canopy, which suggests a disturbance of low intensity. Patch dynamics and gap processes were not pronounced in the stand. Clumping was generally weak and only present at small spatial scales (<5 m) for live trees, and largely non-existent for dead trees; mortality was spatially random in this forest. Although spruce were sparse (5.1% of trees) in the forest relative to fir, which is consistent with predictions that fir will ultimately replace spruce in the absence of disturbance, coexistence seems more likely judging from the age structure and numbers of dead trees. In contrast to almost all spruce-fir forests studied previously, the stand we examined showed no record of major disturbances. Thus this stand falls at the limit of the range of dynamics – from disturbance-structured to near steady-state – encompassed in current thinking about forest ecosystems."

Braumandl, T.F. and M.P. Curran (compilers and editors). 2002. A field guide for site identification and interpretation for the Nelson Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 20.
www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh20.htm

The ESSFdc1 is located "on upper slopes and ridge tops in the Okanagan Highlands and in the Midway Range of the Monashee Mountains." "Extensive stands of Pl [lodgepole pine] exist due to fire history and widespread coarse textured soils. Many of the forests in the ESSFdc1 and MSdm1 have been fragmented through extensive clearcut logging." "The extensive fire history has maintained a predominance of early seral wildlife species."

Braumandl, T.F. and M.P. Curran (compilers and editors). 2002. A field guide for site identification and interpretation for the Nelson Forest Region: Part 2. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 20.
www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh20.htm

The ESSFwc1 is located on the "upper slopes in the Monashee and Selkirk mountains south of Revelstoke." "Relatively long fire return periods have led to few seral stands. Stand replacement often occurs through insects, disease, and wind. Mountain pine beetle is prevalent in this variant."

The ESSFwc4 is found on the "upper slopes in the Monashee and Selkirk mountains south of Revelstoke." "Relatively long fire return periods have led to few stands with seral species. Stand replacement often occurs through insects, disease, and windthrow."

The ESSFwm occupies "upper slopes in the western Purcell Mountains and in the Rocky Mountains from the Cummins River to the Beaverfoot River, and adjacent to the Lower Elk River." "Fire is an important disturbance. A mix of seral and old-growth stands is found." "The extensive fire history has maintained a predominance of early seral species. This subzone is important summer range for deer, elk, moose, and bighorn sheep."

The ESSFvc is located on "mid to upper slopes of the northern Selkirk and Monashee mountains, north of the Trans-Canada Highway to Mica Creek. Extends along valley bottoms in some drainages where icefields, glaciers, and cold air drainage modify the climate." "Abundant precipitation has limited wildfires so that extensive older climax stands are frequent. Windthrow, insects, and diseases are the main disturbance agents."

Campbell, E.M. 1998. Whitebark pine forests in British Columbia: composition, dynamics and the effects of blister rust. MSc thesis. Univ. Victoria, Dep. Biol., Victoria, B.C.

"The composition, structure and dynamics of forests containing whitebark pine (*Pinus albicaulis* Engel.) were investigated in 53 stands in British Columbia. Mountain pine beetle (*Dendroctonus ponderosae*) and white pine blister rust (*Cronartium ribicola*) distribution among stands and incidence (percentage of affected trees) within stands were also examined.

Most recent fires in whitebark pine forests were stand-replacing, although some small trees survived fire. Whitebark pine, and sometimes lodgepole pine (*Pinus contorta*), established in abundance shortly after fire. Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) also frequently colonized stands following fire but took longer to become abundant. The patterns of successional development following fire disturbance were influenced by the life history characteristics of each tree species, availability of seed sources, the nature of the disturbance, characteristics of the pre-disturbance vegetation, and characteristics of vegetation in the surrounding landscape. Forests containing whitebark pine developed along three major successional pathways; differences between the three pathways depended on the relative amounts of lodgepole pine established in post-fire stands (i.e., none, some, abundant lodgepole pine)."

Campbell, E.M. and J.A. Antos. 2000. Distribution and severity of white pine blister rust and mountain pine beetle on whitebark pine in British Columbia. Can. J. For. Res. 30(7):1051–1059.
www.nrcresearchpress.com/doi/abs/10.1139/x00-020

"A major decline in the abundance of whitebark pine (*Pinus albicaulis* Engelm.) has recently occurred in the United States, primarily as a result of white pine blister rust (*Cronartium ribicola* J.C. Fisch. ex Raben.). However, no information on the status of whitebark pine in British Columbia, Canada, was available. We sampled 54 subalpine stands in British Columbia, examining all whitebark pine trees within plots for evidence of blister rust and

mountain pine beetle (*Dendroctonus ponderosae* Hopk.) damage. About 21% of all whitebark pine stems were dead, and blister rust was the most important agent of mortality. Of all living trees sampled, 27% had obvious blister rust infection (cankers), but actual incidence was suspected of being as high as 44% (using all evidence of blister rust). Blister rust incidence and whitebark pine mortality were significantly related to differences in stand structure and the presence of *Ribes* spp., but relationships with local climate and site variables were absent or weak. The lack of strong relationships with climate suggests favourable conditions for the spread of the disease throughout most of British Columbia. Very little evidence of mountain pine beetle was found. Overall, the prospects for whitebark pine in British Columbia do not appear good; a large reduction in population levels seems imminent."

Campbell, E.M. and J.A. Antos. 2003. Postfire succession in *Pinus albicaulis – Abies lasiocarpa* forests of British Columbia. Can. J. Bot. 81(4):383–397.
www.nrcresearchpress.com/doi/abs/10.1139/b03-040

"To examine postfire succession in forests where *Pinus albicaulis* Englem. is common, we conducted chronosequence studies in two areas of contrasting climate in southern British Columbia. Tree age and growth data indicated that *Pinus albicaulis* established rapidly following fire disturbance but that trees also continued to establish in late seral stands. Interactions with *Pinus contorta* Dougl. ex Loud., which grows faster, are pivotal in controlling the population dynamics of *Pinus albicaulis*. Where *Pinus contorta* established abundantly after fire, it dominated stands and limited the abundance of *Pinus albicaulis*, even after the postfire *Pinus contorta* had largely died. In contrast, where few or no *Pinus contorta* established, *Pinus albicaulis* dominated stands throughout most of the successional sequence. Although *Pinus albicaulis* decreases in abundance in late seral stands, we found no evidence that it would be completely replaced by more shade-tolerant species in our study areas. Thus, *Pinus albicaulis* is not only a pioneer species like *Pinus contorta*, even though it establishes in abundance after disturbance, but also a stress tolerator, with population dynamics molded by its ability to grow slowly and persist for long periods under adverse conditions and by bird dispersal of its seeds."

Coupé, R., A.C. Stewart, and B.M. Wikeem. 1991. Engelmann spruce – subalpine fir zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 223–236.
www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap15.pdf

"Lodgepole pine is a widespread seral species after fire. In the driest regions of the zone, lodgepole pine forests frequently dominate the landscape." "Snow avalanche tracks are very common in high-snowfall, mountainous portions of the ESSF. These tracks are usually occupied by a distinctive vegetation that is a tangle of tall shrub and herbaceous species."

Daniels, L.D., Z. Gedalof, M.F.J. Pisaric, C.J.C. Mustaphi, E. Da Silva, H. Marcoux, V. Mather, J. Nesbitt, E. Paul-Limoges, J. Perrault, and C. Steele. 2011. Historic climate-fire-vegetation interactions of the West *versus* East Kootenays: implications of climate change and fire suppression. Prepared for Univ. British Columbia, Dep. Geog., Vancouver, B.C.; Carleton Univ., Dep. Geog., Ottawa, Ont.; and Univ. Guelph, Dep. Geog., Guelph, Ont. www.trench-er.com/public/library/files/kootenay-fire-report.pdf

"In western North America, wildfire is a primary disturbance driving the diversity, age structure, and dynamics of forest. In some forests, climatic warming combined with fire exclusion has created conditions conducive to catastrophic wildfires. Understanding the relationships between wildfire and environmental change is a fundamental concern, particularly in forests near the wildland-urban interface where human lives and property are at risk. In this project, we compared the fire history and forest dynamics of the Joseph-Gold Creek watersheds near Cranbrook in the East Kootenay district and remnant old forests surrounding Nelson in the West Kootenay district of southeastern British Columbia.

We used multiple lines of evidence, including charcoal in lake sediments and analysis of tree rings, to reconstruct historic fire regimes. In both the West and East Kootenay study areas, fire regimes varied significantly with steep elevational gradients. At high elevations, stand-replacing fires burned every 150-300 years according to our lake sediment, fire scar and forest age results. The lake sediment research yielded a 10,000-year fire reconstruction for high elevations (>2000 m.a.s.l.) in the West Kootenay study area. It included 36 fires, burning once every 270 years on average. Fire frequencies peaked 4,000-6,000 years ago, but 2-3 large fires burned during the past 1,000 years. There was at least one large fire in the early 1900s. Forest history reconstructions from tree rings corroborated this evidence. In the West Kootenay study area, high elevations forests established after severe fires that burned up to 340 years ago but many forests established from 1850 to the 1890s, concurrent with the gold rush and European settlement. In the East Kootenay study area, severe fires burned 100-360 years ago. A widespread fire in 1910 affected the forests at all elevations, scarring many trees, and killing even fire-resistant tree species.

In the low-elevation forests, below 1350 m.a.s.l. in the West and 1550 m.a.s.l. in the East Kootenays, there was abundant evidence of frequent, low-severity fires that burned and scarred trees once every 25 to 50 years, on average. Fires burned in late summer of drought years, often during the warm phase of the Pacific Decadal Oscillation, a climate cycle causing warm, dry conditions in the Kootenay region. Despite the historic frequency of fires and recent periods of suitable climate, these forests last burned 56 to 159 years ago. The unusually long fire-free periods are evidence of the strong effects of fire exclusion and suppression during the 20th century. The lack of recent fires was reflected in the composition of low-elevation forests in both study areas. The forest canopies were dominated by thick-barked, fire-tolerant species but subcanopy trees were shade-tolerant, thin-barked species that are susceptible to fire. Although small, the subcanopy trees were the same age as the canopy trees; they established after the last fire and did not represent continuous in-filling of the forest. Historically, the low-severity fires would have killed the smaller thin-barked trees and consumed fine fuels such as needles and branches on the ground. In absence of low-severity fires, dense forests have been perpetuated and ground fuels have accumulated. Paradoxically, by protecting the forests from low-severity fires, we have likely increased the risk of severe wildfires in the low-elevation forests surrounding Cranbrook and Nelson."

Da Silva, E. 2009. Wildfire history and its relationship with top-down and bottom-up controls in the Joseph and Gold Creek watersheds, Kootenay Mountains, British Columbia. MSc thesis. Univ. Guelph, Guelph, Ont. http://trench-er.com/public/library/files/wildfire-history-joseph-gold-creeks.pdf

"This study identifies patterns of historic fire activity that characterise the Joseph and Gold Creek watersheds near Cranbrook, British Columbia as a mixed-severity regime and provide evidence that both bottom-up and top-down controls significantly regulate fire activity. Fire scar chronologies from 33 plots in the watersheds demonstrate that the relative importance of bottom-up controls vary over very short distances. Fire frequency was significantly higher in plots found on a steep southwest-facing sloping compared with the rest of the landscape, an area characterised by xeric conditions. Species distribution was strongly driven by elevation related microclimate and transitioned from fire-resistant to sub-alpine species along elevation gradients, likely reflecting a transition in fire activity – although this could not be substantiated by the fire scar record because of a lack of fire history information. Historic fire activity in this area showed a strong relationship with drought, which may be associated with the warm phase of the Pacific Decadal Oscillation. Similar results were found when analyses were completed using regionally significant fire years. The effects of fire exclusion in the past half century are evident in this fire history reconstruction. The low incidence of fire in the hundred years following a large event in the early 20th century has served to homogenize the landscape and increase fire hazard in the wildland-urban interface."

Dawson, R. 1997. Natural disturbance patterns in the Cariboo Forest Region—summary of results. For. Renewal BC, Res. Program. B.C. Min. For., Cariboo For. Reg., Williams Lake, B.C. www.for.gov.bc.ca/hfd/library/frbc1997/frbc1997mr158.pdf

"The study area sampled in year one of this project included twenty-three 1:20,000 forest cover maps sheets covering an area of approximately 3400 km^2. The study area is located west of the Fraser River on the Chilcotin plateau south of the Itcha Mountain Range. It includes 1520 km^2 in the SBPSxc, 1855 km^2 in the MSxv, 18 km^2 in the ESSFxv and 6 km^2 in SBPSdc and includes most of the area within three draft landscape units. This area is representative of the cold dry climatic conditions found on much of the Chilcotin Plateau."

"A very simplistic analysis of the data indicates that approximately 75% of the area of forested land is under 140 years of age and that over one half of the area is made up of age class patches greater than 1000 ha in size. Although detailed interpretations will have to consider a number of important factors which influence this data, this simplified analysis portraying a disturbance regime characterized by frequent, large fires corresponds to that hypothesized by local ecologists. Two important factors which will have to be considered in further interpretations include the effects of fire suppression over past 40 years and the fact that the forest cover data information used to generate this analysis was not designed to provide accurate estimations of seral age, especially for the older age classes.

The size, frequency and arrangement of forest remnants (older forest patches within a matrix of younger forests) is an interesting result of the natural disturbance history and an important aspect of the landscape pattern from an ecological viewpoint. These remnant patches are thought to play an important ecological role by acting as refugia and 'infection' sources for organisms to recolonize the surrounding disturbed area. They also provide horizontal habitat diversity and provide islands of habitat which may serve as 'stepping stones' for animal movements. In the study area, remnants covered 5.5% of the total forested area and averaged approximately 13 ha in size with much variation around the mean. We have to be aware that many smaller remnants may be below the size resolution provided by the forest inventory database and would therefore be missed by this analysis."

"The data show that 46% of the total study area is composed of forests greater than 100 years of age and that the mature/old component is predominantly in large patches with a high proportion of interior forest. Seventy-eight percent (35/45 as a percent) of this mature and old forest is in patches over 1000 ha in size. Sixty-nine percent (31/46 as a percent) of this mature/old forest is 'interior forest'" buffered from the forest edge.

DeLong, S.C. 1998. Natural disturbance rate and patch size distribution of forests in northern British Columbia: implications for forest management. N.W. Sci. 72 (Spec. Issue No. 1):35–48.
www.vetmed.wsu.edu/org_nws/NWSci%20journal%20articles/1998%20files/Special%20addition%201/v72%20p35%20DeLong.pdf

"A common theme in current forest management policy is that harvesting should be designed to achieve the landscape patterns and habitat conditions that are maintained in nature by natural disturbance regimes. This study was undertaken to determine the influence of climate and topography on disturbance rate and patch size associated with stand replacement wildfire. The purpose was to provide new information to improve forest management guidelines based on approximating natural disturbances currently being implemented in British Columbia.

I modified stand age-class data from inventory records within a geographic information system in order to determine annual disturbance rate and patch size distribution for 9 areas differing in regional climate and topography (plateau vs. montane). Regression analysis was used to determine the influence of climate and gross topography on fire cycle. Patch size distribution was compared graphically and statistically.

Annual disturbance rate and patch size distribution in northern natural forests in British Columbia were clearly related to regional climate and topography. In montane landscapes, a decrease in disturbance rate, a decrease in mean patch size and a decrease in proportion of area in patches > 1,000 ha was associated with increasing precipitation. For plateau areas, topographic units with intermediate precipitation regime had higher disturbance rates and a greater proportion in patches > 1,000 ha. Montane areas which were climatically similar to adjacent plateau areas had a lower disturbance rate and less area in larger patches.

Current biodiversity guidelines appear to underestimate the fire cycle for many areas. Maximum allowable patch size in the current guidelines was lower than the maximum natural disturbance patch size determined for any of the landscapes examined. Current recommendations also suggest to manage for more area in 40–250 ha patches than was evident from the data."

DeLong, C. and D. Meidinger. 2003. Ecological variability of high elevation forests in central British Columbia. For. Chron. 79(2):259–262. http://pubs.cif-ifc.org/doi/abs/10.5558/tfc79259-2

"High-elevation, late-successional forests over much of British Columbia are dominated by Engelmann spruce (*Picea engelmannii* Parry ex. Engelm.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). Throughout the range of these forests, however, there is a wide variation in natural disturbance and successional dynamics as influenced by diverse climate and topography. We divided these high elevation forests into four groups arranged along a regional climatic gradient that affects forest composition, structure and disturbance regime. For each, we describe the climate, topography, major vegetation, and natural disturbance dynamics. We suggest that management practices reflect the ecological variability demonstrated for these high elevation forests."

DeLong, C., D. Tanner, and M.J. Jull. 1994. A field guide for site identification and interpretation for the Northern Rockies portion of the Prince George Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 29.
www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh29.htm

"The ESSFmv2 occurs predominantly east of the Rocky Mountain divide as far south as Willmore Wilderness Park and as far north as the Peace Arm of Williston Reservoir. It generally occurs between 1000 – 1400 m, and above the SBSwk2." "Like most ESSF forests, climax forests in the ESSFmv2 are dominated by Engelmann spruce and subalpine fir. A greater incidence of fire than is found in most ESSF forests has led to a larger portion of the stands being dominated by lodgepole pine."

"The ESSFmv4 occurs predominantly east of the Rocky Mountain divide as far south as the Peace Arm of Williston Reservoir and as far north as Cypress Creek. It generally occurs between the elevations of 1000 – 1400 m, and above the SBSwk2 or BWBSwk2." "Like most ESSF forests, climax forests in the ESSFmv4 are dominated by Engelmann spruce and subalpine fir. However, because fire occurs more frequently than in most of the ESSF in the region, a larger portion of the stands are dominated by lodgepole pine."

"The ESSFwk2 occurs predominantly west of the Rocky Mountain divide as far south as the Morkill River and as far north as the Ospika Arm of Williston Reservoir. It occurs above the ICH at its southern boundary, and the SBS over the rest of its range. Throughout its range it occurs below the ESSFwc3." "Climax forests are dominated by Engelmann spruce and subalpine fir.

Very few seral stands exist in this variant because of the lack of fire history although some lodgepole pine stands do exist, especially at the southern end of the subzone. Sitka alder (*Alnus crispa* ssp. *sinuata*) swales are common, especially on north-facing slopes. These have been determined to be very old (200 + years)."

Dorner, B. 2001. Natural landscape pattern and range of natural variability in the Arrow TSA. Arrow Innovative For. Pract. Agreement. Final rep.

Brigitte Dorner "used stand-age maps of the Arrow IFPA to estimate pre-settlement (1700–1860) disturbance return intervals. For the ESSFwc1, intervals range from 90 to 807 years and for the ESSFwc4 from 105 to 508 years. Her results showed that disturbance rates were not stationary during the past, and that the early 20th century was a period of high disturbance rates, followed by a decline during the second half. While this pattern was especially strong in the ESSFwc4, it was absent for the ESSFwc1, where disturbance frequency was low during the first part of the 20th century. Note that Part 3 of this report contains our re-analysis of the Arrow Forest District data." (cited by Wong et al. 2003 www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh53.htm)

Doyle, C. 1988. The fire history of the Ottertail fire management unit in Yoho National Park. Selkirk College, Castlegar, B.C. Wildland Recreation Tech. Rep. (student pap.).

Enache, M.D. 2006. Mid to late Holocene fire and climate dynamics inferred from lake sediments from Interior British Columbia, Canada. PhD thesis. Queen's Univ., Dep. Biol., Kingston, Ont.

"A number of distinct charcoal morphotypes were defined in this study and used along with diatom assemblages from lake sediments to investigate the relationships between fire and climate at decadal through millennial scales from the Interior British Columbia. Charcoal fragments were classified into seven distinct morphotypes according to their morphological and structural characteristics using optical microscopy. The contemporaneous relationship between charcoal morphotypes and recorded area burned was assessed from three lakes in different biogeoclimatic zones [ESSF, IDF, SBS] between 1919-2000. The distribution of each charcoal morphotype showed distinct differences over time. In Prosser Lake [IDF-ESSF boundary] type-M charcoal was significantly correlated to area burned around Prosser Lake at radii up to 20 km, whereas type-C morphotype was correlated to area burned at a radius <10 km, and type S at a 20-km radius. In Opatcho Lake, morphotype M was the only charcoal type significantly correlated with area burned. Charcoal from Big Lake was inversely related to past area burned, suggesting important contribution from secondary deposition. The strong correlation between type-M charcoal and area burned was used to develop an index of area burned. The charcoal-morphotype approach at inferring past fires was further assessed by longer-term reconstructions of climate at a sub-decadal resolution over the past 400 years and centennial-scale resolution over the last six millennia in sediment cores from Opatcho Lake. Climate proxies were developed using variations in diatom assemblages and supported with regional proxies of temperature and precipitation. In both cases, the reconstructions indicates that synoptic-scale climate variations were significantly related to morphotype-based reconstruction of fire, but were not related to total charcoal. This new technique suggests that fires were ~5 times more common than present day between 4500-6000 yrs B.P., a well known period of aridity. Models suggest that B.C. will get increasingly arid. A similar fire regime to that observed in the mid Holocene should be expected."

Gray, R.W., B. Andrew, B.A. Blackwell, A. Needoba, and F. Steele. 2002. The effect of physiography and topography on fire regimes and forest communities. Prepared for Habitat Conservation Trust Fund, Victoria, B.C. www.for.gov.bc.ca/hfd/library/FIA/2002/FIA2002MR009.pdf

"The historic fire regimes found in south aspect NDT3 and NDT4 polygons sampled in 5 forest districts (Invermere [IDFdm2, MSdm1], Cranbrook [IDFdm2, MSdk], Kamloops [IDFdk1, IDFxh2, MSxk1], Lillooet [PPxh2, IDFdk1], and Squamish [IDFww, ESSFmw]) were characterized by high fire frequency with narrow variability around the mean, and variable intensity. Mean fire intervals (MFI) recorded for the 5 sites ranges from a low of 6.5 for Lillooet and a high of 17.9 for Invermere. The MFI's recorded are some of the lowest numbers recorded in the province.

The results of the analysis on south aspects suggest frequent, mixed-severity fire regimes have influenced historic stand structure and ecosystem processes in biogeoclimatic subzones and variants currently considered to have experienced infrequent stand-replacement fire regimes. This is true for the MSdk in Cranbrook, MSdm1 in Invermere, MSxk in Kamloops and Lillooet, and the ESSFmw in Squamish. Additionally, significant issues exist in some Forest Districts concerning inaccuracies in the current mapped distributions of biogeoclimatic units. These identified discrepancies can have significant consequences where the conservation of biodiversity is concerned. The current designation of many of these biogeoclimatic units as Natural Disturbance Type 3 warrants further investigation. Fires appear to be of more mixed-severity as opposed to infrequent, high-severity."

Greene, G.A. 2011. Historical fire regime of the Darkwoods: quantifying the past to plan for the future. MSc thesis. Univ. British Columbia, Dep. Geog., Vancouver, B.C. https://circle.ubc.ca/handle/2429/37139

"This study quantifies the fire history of the Darkwoods; a 55,000 ha property in the South Selkirk Natural Area of southeastern British Columbia, owned and managed by the Nature Conservancy of Canada. Fire scar and tree cohort chronologies from 45 plots, extending from the years 1406 – 2010, were used to determine the temporal and spatial variability of historic fires in ~ 4,000 ha of the southeastern-most watershed of the property, and to assess the accuracy of provincial Natural Disturbance Type (NDT) classes for the study area. In light of a mixed-severity fire regime, new and novel methods of historic fire mapping using Inverse Distance Weighting methods in a GIS were also analyzed. Using logistic regression, the spatial variation of fires at the tree- and plot-levels differed greatest by elevation, but fires at the tree-level also varied by slope steepness and slope aspect. Anthropogenic influences on the occurrence of fire over time were also evident, but only after 1945, when the occurrence of fire dropped significantly likely due to the introduction of modern methods of fire suppression in the 1940s. Results indicate a mixed-severity fire regime for the study area, and the presence of numerous fire scars in mid- and high- elevation plots, in conjunction with mean fire return intervals less than 100 years, provide evidence that conflicts with provincial NDT designations. Including high-elevation stand ages, determined from increment cores, provided evidence of the absence of fire and helped refine estimates of fire boundaries, particularly in and around areas experiencing mixed- and high-severity fires. Spatial Mean Fire Intervals were longer than those calculated at the tree-, plot- and watershed-levels, reflecting the degree to which a mix of high-severity, stand-replacing fires, with low- and moderate-severity, stand-maintaining fires, can lengthen mean return intervals across a mixed-fire landscape."

Hawkes, B., W. Vasbinder, and C. DeLong. 1997. Retrospective fire study. Final report. Fire regimes in the SBSvk and ESSFwk2/wc3 biogeoclimatic units of northeastern British Columbia. McGregor Model For. Assoc., Prince George, B.C.
www.resourcesnorth.org/publications/RetrospectiveFireStudy.pdf

"A retrospective study of fire was initiated in the north-eastern interior of British Columbia as a part of the McGregor Model Forest Association's larger goal to determine the ecological processes that influence the forest landscape in this area. The area of study encompassed approximately 1.3 million hectares of forested and mountainous terrain stretching along the western side of the Rocky Mountains within the SBSvk, ESSFwk2, and ESSFwc3 biogeoclimatic units. British Columbia Ministry of Forests digital forest inventory data was heavily relied upon to determine the age and patch characteristics of the study landscape. Using this data the objectives have been to address the knowledge gap regarding the historical fire regime in the study area. Estimates have been derived of historical patch size, patch shape, and rate of disturbance in the study landscape. Analysis has also included comparison of historical patch size estimates with fire records for the period 1950–1992, as well as an examination of the seasonality of fire occurrence for both natural and human-caused fires in this time period. Results of some sample plot data collected within the study area are also presented.

Results indicated that the fire cycle for these cool and wet mountainous subzones seems to be much longer than initially estimated and that both the SBSvk and ESSFwk2/wc3 biogeoclimatic units should be classified as NDT1 systems in the provincial Biodiversity Guidebook. Patch sizes within the study area exhibit a north-south difference with the northern half of the study area characterized by larger disturbance patches than the southern half of the study area. It appears as though the importance of very large patches in this landscape is underestimated in the Biodiversity Guidebook. Patch shape complexity differs significantly between the northern and southern sections of the study area. It is likely that the higher proportion of very large patches in the northern portion of the study area is contributing to this north-south difference."

Hawkes, B., W. Vasbinder, C. Opio, and C. DeLong. 1997. Retrospective fire study. Interim report. Fire in the SBS & ESSF biogeoclimatic zones of British Columbia—a literature review. McGregor Model For. Assoc., Prince George, B.C.
www.resourcesnorth.org/publications/
RetrospectiveFireStudy(LiteraryReview).pdf

"Fire regimes in the Sub-Boreal Spruce (SBS) and Engelmann Spruce – Subalpine Fir (ESSF) biogeoclimatic zones of British Columbia are reviewed. In the SBS and ESSF zones, fire regime characteristics (fire weather, fire intensity, fire size and pattern, fire frequency) are related to the biotic and abiotic conditions existing in each zone. Recent work in subzones of these areas indicates that past estimates of fire frequency may be high. Although current research in the SBS and ESSF zones is adding to the base of knowledge in fire ecology for the central interior of the province, there are still many information gaps which need to be addressed. Landscape fire modelling is discussed as a method for narrowing some of these knowledge gaps and an outline for three fire landscape models currently under development is provided."

Heathcott, M.J. and E.A. Johnson. 1987. Historical fires in Mount Revelstoke and Glacier National Parks: a review of existing information. Univ. Calgary, Dep. Biol. Sci. and Kananaskis Cent. Environ. Res., Calgary, Alta.

Hebda, R. 1999. Long term natural disturbance regimes of the ESSF. For. Renewal BC, Res. Program. Univ. Victoria, Biol. Dep. and School of Earth and Ocean Sci., Victoria, B.C.
www.for.gov.bc.ca/HFD/library/FRBC1999/FRBC1999MR85.pdf

"The charcoal record clearly demonstrates a major role for fires on the Sicamous Creek Lake area though few obviously visible charcoal layers were recorded in the lake core. The response to fire disturbance however has differed in the warm and relatively dry middle Holocene (SCL-3) compared to the late Holocene (SCL-4 and Woodpecker section).

Between 6000 and 4000 yBP several stand destroying fires followed by successional recovery are obvious. The fire just before the 247.5 cm level led to a sharp decline in pine followed by a sharp rise in *Artemisia*, a response similar to that noted for the much drier Mt. Kobau in the southern Okanagan after the historic fire in the 1930s. Birch and Douglas-fir/larch followed immediately afterwards as part of the post-fire succession. Spruce and fir followed the birch and Douglas-fir peaks. A similar disturbance response and recovery sequence occurred just after the 225 cm level. Other narrow sharp peaks of alder values suggest that such extensive stand-destroying events occurred in the vicinity of the lake several times during the interval. It may be that relative severity and repeated burning during this interval maintained the area in some sort of disclimax state. Stand-destroying fire frequency was once every 350 years or less.

After 4000 YBP such obvious responses to fire no longer occur. Alder values never reach as high as in the previous zone. Birch and Douglas-fir/larch responses appear at best muted. The predominance of fir over spruce in the pollen rain suggests that fires were mostly not of a stand-destroying nature.

Charcoal however does occur in the record and there are several marked alder peaks suggesting that disturbance did occur. Based on these large peaks stand-destroying fires occurred about every 750 years. There is a notable interval without charcoal peaks just after 3400 YBP when fir predominates over spruce. The Woodpecker section reconstruction reveals that fires probably burned through the stand in the post 4000 YBP interval, but perhaps mainly along the ground or in a patchy manner. The shift to preponderance of spruce over fir in the last 1000 years or so suggests that these low impact fires may have become more frequent recently."

Heinrichs, M.L. 1999. A Late-Quaternary paleoecological analysis in the Engelmann Spruce–Subalpine Fir biogeoclimatic zone of the Okanagan/ Ashnola region, British Columbia, Canada. PhD thesis. Univ. Victoria, Dep. Sci., Victoria, B.C.
www.collectionscanada.gc.ca/obj/s4/f2/dsk1/tape9/ PQDD_0007/NQ41358.pdf

"A multi-proxy paleoecological analysis from three sites in the high-elevation Engelmann Spruce–Subalpine Fir forests of the Okanagan and Ashnola regions was undertaken. Using pollen, plant macrofossils, and microscopic charcoal, the vegetation and natural disturbance history was reconstructed.

At Mt. Kobau, Crater Mountain, and Cathedral Provincial Park, the late-glacial vegetation consisted of an *Artemisia* steppe. Inferred climate from this period is cold and dry. Rapid warming occurred in the early Holocene, approximately 10,000 to 9500 yr BP, and vegetation during the xerothermic interval varied from grasslands at Mt. Kobau, open *Pinus* parklands at Crater Mountain, and closed *Pinus* forests at Cathedral Provincial Park. An increase in available moisture during the mid-Holocene from approximately 7000 to 4000 yr BP, resulted in increased fire severity at all three sites. Vegetation responded to the moisture and fire regimes, resulting in open *Pinus* parkland at Mt. Kobau, fire-successional stands of *Pinus contorta* at Crater Mountain, and increasing amounts of *Abies lasiocarpa* and *Picea engelmannii* at Cathedral Provincial Park. Late Holocene cooling resulted in Engelmann Spruce–Subalpine Fir forests at all three sites.

These forests differ in composition, history, and response to disturbance. Furthermore, impacts of future climate change and disturbance will be expressed differently at these sites. These differences are of significant importance in resource management strategies."

Heinrichs, M.L., R.J. Hebda, and I.R. Walker. 2001. Holocene vegetation and natural disturbance in the Engelmann Spruce – Subalpine Fir biogeoclimatic zone at Mount Kobau, British Columbia. Can. J. For. Res. 31(12):2183–2199.
www.nrcresearchpress.com/doi/abs/10.1139/x01-157

"The vegetation and natural disturbance history of the Mount Kobau area, in the Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) – subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) (ESSF) forest of southern British Columbia, was reconstructed using pollen, plant macrofossils, and microscopic charcoal. Late-glacial vegetation, occurring from about 11 000 ^{14}C years BP, consisted of an *Artemisia* steppe under a cold and dry climate. Rapid warming occurred at the start of the Holocene, approximately 10 000 to 9500 years BP, and grassland steppe vegetation prevailed. Moisture increased during the mid-Holocene, from approximately 7000 to 3800 years BP, and fires may have occurred more widely and burned more severely. Open lodgepole pine (*Pinus contorta* Dougl. ex Loud.) parkland occupied the mountain summit. Late-Holocene cooling at 4000 years BP resulted in the establishment of modern ESSF forest. The vegetation and inferred climate history confirm a broad three-stage (warm dry – moderate moist – cool moist) regional climatic pattern of the Holocene. Under future anticipated climate change, the high-elevation, dry ESSF forests in southern British Columbia may be replaced by grasslands."

Heinrichs, M.L., R.J. Hebda, I.R. Walker, and S.L. Palmer. 2002. Postglacial paleoecology and inferred paleoclimate in the Engelmann spruce–subalpine fir forest of south-central British Columbia, Canada. Palaeogeog., Palaeoclimatol., Palaeoecol. 184(3-4):347–369.
www.sciencedirect.com/science/article/pii/S0031018202002742

"Pollen, charcoal, and plant macrofossil analyses reveal five postglacial vegetation periods at Crater Lake, Crater Mountain, British Columbia. The first period, beginning ca. 11 400 ^{14}C yr BP was characterized by *Artemisia* steppe-tundra. At 9700 ^{14}C yr BP, *Pinus* parkland developed, and by 6700 ^{14}C yr BP was replaced by fire-successional *Pinus*-dominated Engelmann spruce and subalpine fir forest (ESSF). At 3800 ^{14}C yr BP, *Picea* became a more important element of the forest, and modern forest structure and composition developed by 1600 ^{14}C yr BP. Comparison of the fossil vegetation and fossil midge data derived from several ESSF sites in the southern interior reveals (1) similar late-Pleistocene vegetation and climate at all sites, (2) three distinct Holocene climatic stages: warm/dry, warm/moist, and cool/moist, (3) confirmation of the warm/moist period as a distinct climatic period, and (4) distinct differences in Holocene vegetation change among the sites. The driest and warmest site was most sensitive to climatic change, whereas cooler, moister sites were less sensitive. The present east–west climate gradient originated with postglacial warming at the beginning of the Holocene. Vegetation response to climate change and natural disturbance in these sites is strongly controlled by local site characteristics. These characteristics may have implications for forest, environment, and resource management."

Higgs, S.P.W., A.J. Dickhout, C.N. Service, and T.M. Christou. 2010. Dendrochronology and alpine fire history in Mt. Revelstoke National Park. Univ. Victoria, Phys. Geog. Field Course GEOG 477, Victoria, B.C.
www.geog.uvic.ca/dept2/faculty/smithd/477/2010/2010_02_paper.pdf

"Our understanding of the historical fire regime in Mount Revelstoke National Park is growing. A fine scale fire history study in Mount Revelstoke National Park was undertaken to better understand patterns of fire on the landscape at the study site. The study was conducted using dendrochronology to build a living chronology and date dead trees stands to identify fire events. Five fire events between the dates of 1945 and 1999 [1945, 1965, 1992, 1996, 1999] were identified in three stands within the site. A large degree of variation was observed within the samples kill dates. Cooler and wetter weather patterns and fire suppression from park policies may explain the small spatial extent of the fires. The fire events found in this study were not recorded in other fire studies within the area. Results from this study provide an intriguing illustration of the broader interplay between anthropogenic and abiotic processes in alpine environments."

Holt, R.F. and M. Machmer. 2005. Development of a restoration and monitoring strategy in relation to fire effects and natural disturbances in West Arm Provincial Park. Prepared for BC Parks, Nelson, B.C. www.veridianecological.ca/publications/WestArm_Veridian_FinalReport.pdf

"The Salmo Wet Cold Engelmann Spruce – Subalpine Fir Variant (ESSFwc5) forms a narrow transitional band (1,500 – 1,650 m on warm aspects, and from 1,450 – 1,600 m on cool aspects) between the ICHmw4 and the ESSFwc6. The climate is characterized by cool, moist summers and cold, wet winters with moderately heavy snowfall. Frozen soils are relatively rare under forested conditions. Moisture deficits in late summer are rare and are generally restricted to very dry sites. Climax vegetation on zonal sites is characterized by an overstory of Bl [subalpine fir] and Se (Engelmann spruce), with Cw [western redcedar] and Hw [western hemlock] in the understory as intermediate trees. Pl [lodgepole pine] and Fd [Douglas-fir] occur on drier sites. Understory shrub vegetation generally includes white flowered rhododendron, black huckleberry and Utah honeysuckle. Fire cycles are relatively long, small-scale disturbances are common, and mountain pine beetle is an important disturbance agent where Pl occurs.

The Ymir Wet Cold Engelmann Spruce – Subalpine Fir variant (ESSFwc6) is found above the ESSFwc5 (1,650 – 1,950 m on warm aspects and 1,550 – 1,850 m on cool aspects). The ESSFwc6 is characterized by cool, moist summers and cold, wet winters with moderately heavy snowfall. Moisture deficits in late summer are rare and are generally restricted to very dry sites. Cold soils and air temperature are limiting factors for tree growth. Climax vegetation on zonal sites includes an overstory of Bl and Se, with an understory often dominated by white flowered rhododendron, black huckleberry and gooseberry. Fire frequency is very low and old seral stands are common. Relatively small-scale disturbances from insects, disease and windthrow characterize stand dynamics and lead to regeneration within canopy gaps. Pl occurs occasionally on drier south facing sites."

Jull, M.J. 1990. Long-term stand dynamics in high-elevation Engelmann spruce – subalpine fir forests. MSc thesis. Univ. British Columbia, Fac. For., Vancouver, B.C. https://circle.ubc.ca/handle/2429/28992

"For the high-elevation Engelmann spruce – subalpine fir (ESSF) biogeoclimatic zone of southwestern British Columbia, there is little empirical data on the long-term dynamics of subalpine spruce–fir stands. A lack of a long-term perspective on the growth and development of stands in the ESSF zone hinders both ecological research and silvicultural planning in the ESSF forest.

A broadly-focussed pilot study on long-term Engelmann spruce–subalpine fir stand dynamics in the ESSF zone was designed to begin to address this deficiency. This study used two methodological approaches to gain insights into long-term stand dynamics: 1) a retrospective approach to examine historical patterns of: i) post-fire conifer regeneration, ii) post-establishment stand structure development, and; iii) basal area production and accumulation in ESSF spruce–fir forests, and; 2) a chronosequence approach to examine overall stand basal area development over a 575-year chronosequence, which is not amenable to detailed retrospective examination.

In order to reconstruct the patterns of postfire regeneration and subsequent stand development, measurements of tree age, diameter, radial increment, and height were collected in 8 mesic, 45- to 110-year-old fire-origin stands of Engelmann spruce (*Picea engelmannii* Parry. ex Engel.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) in the ESSFwm and ESSFdc2 biogeoclimatic subzones of the North Cascades mountains. The results of the stand reconstruction were also used to aid in the interpretation of the chronosequence, which was based on basal area and age data from both the retrospective study sites, and the published literature.

Based on the graphical analysis and discussion of the data collected in this pilot study, the following features of long-term stand development were noted in subalpine Engelmann spruce–subalpine fir stands: 1) Postfire conifer re-establishment on these burned ESSF sites was slow and erratic; the re-establishment period was 30 to 50 or more years in duration; 2) There appeared to be no consistent or predictable postfire patterns of conifer establishment on the various sites, either over time, or on a site-to site basis; 3) During postfire regeneration and immature stand development, there appeared to be no consistent differences between Engelmann spruce and subalpine fir, either in terms of i) postfire regeneration establishment, or ii) height development; 4) Fire-origin spruce–fir stands in the ESSF zone rapidly develop a complex stand structure, possibly due to the gradual and prolonged patterns of regeneration ingress on these sites; 5) Trees which have initial advantages in height or other competitive advantages over other trees on the site during the establishment phase tend to retain dominant crown positions in the stand at much later stages of development; 6) The relationship of periodic basal area increment (BAI) to initial basal area stocking in immature spruce–fir stands suggests that stand increment is optimized above a critical stand density; 7) The initial basal area level necessary to optimize BAI appears to increase with stand age; and 8) Apparent trends from a 575-year chronosequence of Engelmann spruce–subalpine fir stand development suggests that stand basal area tends to peak, on average, between the ages of 70 and 150 years of age. Subsequently, basal area tends to gradually decline and eventually stabilize between the ages of 300 to 400 years of age.

Based on these results, preliminary recommendations were proposed for the long-term silvicultural management of ESSF spruce–fir forest types. Also, the research priorities necessary for building on the results of this pilot study were identified."

Kopra, K. 2003. Effects of natural disturbance and harvesting on the landscape and stand level structure of wet, cold Engelmann spruce–subalpine fir forests of south-central British Columbia, Canada. MSc thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/14291

"Engelmann Spruce–Subalpine Fir (ESSF) forests of interior British Columbia have increasingly become the target of forest harvesting in the past 40 years. Over the past decade, increasing public concern over maintaining biodiversity and ecological health within forests has brought about two primary pieces of legislation—The Forest Practices Code of 1995 and *The Forest and Range Practices Act* of 2002—that shape the current paradigm directing forest management. This paradigm maintains that biological diversity can be preserved by designing forest harvesting practices that result in regenerated forests that closely mimic naturally disturbed forests. It has been suggested that fire is the primary form of natural disturbance in ESSF forests. To date, there has been little knowledge gained about the natural disturbance patterns in ESSF forests, leaving forest managers with little guidance as to how to emulate these patterns. In this study, I sought to quantify both landscape-level and stand-level differences between naturally disturbed and harvested forests in the North Thompson variant of the wet, cold subzone of the ESSF (ESSFwc2) using the Geographical Information System Arcview and field measurement techniques. A decrease in the amount of old-growth forest as well as a decrease in the mean disturbance interval from naturally disturbed to harvested forests was found. Both patch size and patch size variability decreased with harvesting in older age classes and increased with harvesting in young age classes. A decrease in the amount of coarse woody debris and snags from naturally disturbed to harvested stands, as well as a significant difference in tree species composition between naturally disturbed and harvested stands was found. If emulation silviculture is the goal of forest management, this study concludes that the current harvesting method of clearcutting is failing to do so and, therefore, alternative harvesting methods and/or non-timber outputs should be considered."

Kopra, K. and M.C. Feller. 2007. Forest fires and old-growth forest abundance in wet, cold, Engelmann spruce – subalpine fir forests of British Columbia, Canada. Nat. Areas J. 27(4):345–353.
www.bioone.org/doi/abs/10.3375/0885-8608%282007%2927%5B345%3AFFAOFA%5D2.0.CO%3B2?journalCode=naar

"The amounts of old-growth forest present under current and pre-harvesting era disturbance regimes in the dominant higher elevation (900–2300 m) forests in eastern British Columbia (B.C.) – wet cold Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) – subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) forests (ESSFwc), and one important group of ESSFwc forests, the Northern Monashee (ESSFwc2) biogeoclimatic variant – were quantified using a GIS forest age database, with the assumption that old-growth forests were forests >140 years old. This was done in order to inform natural disturbance based management in this part of British Columbia. Database constraints restricted the analysis to the post-1800 period only and resulted in estimation of a range of old growth for any time period. The oldest trees in old-growth forests do not necessarily indicate when the forests were last disturbed by fire, as ^{14}C dating of charcoal indicated that, for two of five 210- to 320-year old stands sampled, the most recent fire event probably occurred over 1000 years ago. The amount of old growth in both ESSFwc and ESSFwc2 forests, since 1800, decreased to a minimum in the mid to late 1800s, then increased. In the case of the ESSFwc2, this increase occurred until the 1960s before the amount of old growth decreased again. Amounts of old growth in 2003 (58–59% of the forested area) were within the pre-harvesting era range of 30–60% in ESSFwc2 forests, but may be above the range of 20–50% in ESSFwc forests. Old-growth forests have dominated most subalpine landscapes in eastern B.C. for at least the last several decades. If management of ESSFwc forests is to emulate historical disturbance regimes, greater protection of old-growth ESSFwc forests than at present will be necessary."

Lindgren, S. and K.J. Lewis. 1997. Ecological processes in the McGregor Model Forest: interactions with insects and pathogens. McGregor Model Forest Association, Prince George, B.C. www.resourcesnorth.org/publications/InteractionsWithInsectsAndPathogens.pdf

"The purpose of this synthesis paper is to provide a summary of the current knowledge or hypotheses regarding the interactions of insects and diseases with natural ecological processes, and to make some general interpretations with respect to ecosystem function. The development of any model that attempts to describe natural processes is difficult because of the complexity of natural systems, the interrelationships that exist between various components, and the different perspectives that result when the system is viewed at different temporal and spatial scales. For example, beetle outbreak and resultant mortality on an area when viewed over a short time period is seen to have one effect on the system, but when the same area is viewed over a time span of 300 years, the effect is seen differently. Therefore we have to be careful to define spatial and temporal scales when discussing or modelling agents of ecosystem or landscape change.

A landscape is normally thought of as a somewhat arbitrary area encompassed by a view or scenery. In the discipline of landscape ecology, the term landscape has been formalized in order to make the term useful. Thus, a landscape is an area of land, which contains a repetition of a given set of attributes. When the set of attributes change, the landscape is also changed. In the McGregor Model Forest, we are concerned with the forested landscape. The attributes of this landscape, in a retrospective context, would be a mosaic of forested areas of various ages. Each unit of this mosaic consists of a number of similar stands, with a similar successional history. Therefore, we also discuss agents of change that occur at a stand level but that affect the overall landscape."

Masters, A.M. 1989. Forest fire history of Kootenay National Park, British Columbia. Can. Parks Serv., Kootenay Natl. Park, Radium Hot Springs, B.C.

"This study uses time-since-fire distribution analysis to determine forest fire frequency for 1400 square kilometre Kootenay National Park, located on the west slope of the Rocky Mountains, British Columbia. The time-since-fire distribution is comprised of at least two spatial and two temporal fire regimes. Mean fire return intervals (MFRI) for the Kootenay/Sinclair and Vermillion areas ranged from 92 to 165 years, respectively, and from 75 to 267 years for the Vermillion Valley prior to and after 1768. MFRI for the whole park was 127 years. Elevation, aspect, and proximity to the Great Divide had little direct effect on the distribution of forest ages and could not be linked to fire frequency using the methods employed. A fire suppression policy since park establishment in 1919 has had little effect on the time-since-fire distribution. A period of cool climate may be responsible for the present, bell-shaped age-class distribution of the park's forests. Findings of the study are discussed in relation to fire control and prescribed fire use in the park."

Masters, A.M. 1990. Changes in forest fire frequency in Kootenay National Park, Canadian Rockies. Can. J. Bot. 68(8):1763–1767. www.nrcresearchpress.com/doi/abs/10.1139/b90-227

"Time-since-fire distribution analysis is used to estimate forest fire frequency for the 1400 km^2 Kootenay National Park, British Columbia, located on the west slope of the Rocky Mountains. The time-since-fire distribution indicates three periods of different fire frequency: 1988 to 1928, 1928 to 1788, and before 1788. The fire cycle for the park was > 2700 years for 1988 to 1928, 130 years between 1928 and 1788, and 60 years between 1778 and 1508. Longer fire cycles after 1788 and 1928 may be due, respectively, to cool climate associated with the Little Ice Age and a recent period of higher precipitation. Contrary to some fire history investigations in the region, neither a fire suppression policy since park establishment in 1919, nor the completion of the Windermere Highway through the park in 1923 appear to have changed the fire frequency from levels during pre-European occupation. Spatial partitioning of the time-since-fire distribution was unsuccessful. No relationship was found between elevation or aspect and fire frequency."

Meidinger, D., A. McLeod, A. MacKinnon, C. DeLong, and G. Hope. 1988. A field guide for identification and interpretation of ecosystems of the Rocky Mountain Trench, Prince George Forest Region. B.C. Min. For. Lands, Res. Br., Victoria, B.C. Land Manag. Handb. 15. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh15.htm

"The ESSFo [ESSFmm] occurs in the northern half of the area covered by this guide. It borders the ESSFb [ESSFvc] in the south, and stretches as far north as the Dore River on the western side of the valley, and Forgetmenot Creek on the eastern side." "Climax forests are dominated by Engelmann spruce and subalpine fir. Wildfires are more common in this subzone than in the ESSFb [ESSFvc], and thus seral species such as lodgepole pine and limber pine are present, especially on drier sites."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 1. Very dry climatic region. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

In the ESSFd [ESSFxc], in the eastern part of the study area, "past wildfires have had a pronounced influence on the existing forest and understory floristic composition. Crown fires were common and many areas now consist of young and maturing seral Pl [lodgepole pine], or Pl and Se [Engelmann spruce] mixed stands, with a dominant understory of *Vaccinium scoparium*."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 2. Dry and subcontinental climatic regions. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2.

www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

The ESSFe [ESSFdc] is in the southwestern and northeastern parts of the study area. "Past fires have had less influence on the forest and understory floristic composition in this subzone than in the drier ESSFd [ESSFxc]. However, crown fires were common and some areas are now primarily young and maturing seral mixed stands of Pl [lodgepole pine] and Se [Engelmann spruce]."

Mori, A.S. and K.P. Lertzman. 2011. Historic variability in fire-generated landscape heterogeneity of subalpine forests in the Canadian Rockies. J. Vegetation Sci. 22(1):45–58.

http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2010.01230.x/abstract

"This study evaluates historical changes in landscape structure and heterogeneity in subalpine forests. We use response to severe fires in 2001 and 2003, along with historical reconstructions to examine crown-fire effects on landscape heterogeneity and to assess, comparatively, effects of fire exclusion management in the 20th century.

Using a landscape-level model based on a fire-origin stand age map, we reconstructed decadal burned areas within the landscape for 1750–2000 (forming reconstructed landscapes). Landscape pattern was analysed for each reconstructed landscape map, and we compared landscape pattern indices (total area, number of patches, mean patch area, patch area variation, largest patch index, edge density, perimeter–area ratio, landscape shape index) with those in 2005 after recent large fires.

After large fires in 1926, connectivity of the KNP [Kootenay National Park] landscape increased and its diversity was quite low. After 2001 and 2003 fires, the post-fire landscape of 2005 was highly heterogeneous in terms of size, variation, edge density and perimeter–area ratio of the remnant forest patches. Since the decline in occurrence of large fires after 1926 reflected a period of wet weather, fuel build-up resulting from landscape homogenization within the 20th century landscape could not be attributed solely to fire exclusion. This period without fires greatly enhanced connectivity of late-successional forests that finally burned in 2001/2003, but connectivity was within the historical range for these forests. The gradual increase in stand connectivity before recent large fires may indicate that fire exclusion was less responsible than often believed for fuel build-up in these fire-susceptible older forests.

The large fires at the beginning of the 21st century are within the natural range of disturbances for this landscape, and do not stand out as 'human-induced disasters' in their effects on landscape patterns. Such stochastic large disturbances contribute to maintenance of highly heterogeneous landscape structure, which is important for many taxa and natural ecological processes. Identifying future probability of such large disturbances and their ecological roles should be incorporated into management of these dynamic, disturbance-prone systems."

Parish, R. 1997. Age and size structure of the forest at Sicamous Creek. In: Sicamous Creek silvicultural systems project: workshop proceedings. Apr. 24–25, 1996, Kamloops, British Columbia, Canada. C. Hollstedt and A. Vyse (editors). B.C. Min. For., Res. Br., Victoria, B.C. Work. Pap. 24, pp. 16–31.
www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp24.htm

"Dendrochronological techniques and stem analysis are used to develop a history of the subalpine fir – Engelmann spruce forest at Sicamous Creek. The forest originated in the 1650s.

A forest of dense patches with moderately growing dominants and a suppressed subcanopy probably existed until the mid-1800s when a large number of trees were removed from the canopy. A period of recruitment and release of suppressed trees occurred from 1850 to 1900. Small-scale disturbances by insects (most likely western balsam bark beetle) and diseases (e.g., *Armillaria* and Indian paint fungus), which are all prevalent in the current stand, are likely responsible for this pattern of release. Growth rates for the post-1850 cohort were considerably higher than previous growth rates, possibly in response to the open canopy and the increased temperatures associated with the end of the 'Little Ice Age.'"

Parish, R. 2001. Impact of changing disturbance regimes and patch size on stand structure of Interior and Coastal high-elevation forests. For. Renewal BC, Res. Program. B.C. Min. For., Res. Br., Victoria, B.C.
www.for.gov.bc.ca/HFD/library/FRBC2001/FRBC2001MR35.pdf

"The high-elevation forests of British Columbia are rapidly becoming an important source of both wood products and recreational areas. Knowledge of the effects of disturbance on high-elevation forests expands the basis for sound management decisions and provides a rationale to support empirical studies of forest management options. This project examined stand structure in two interior and two coastal high elevation forests. We analyzed the size, age, and spatial distributions of populations of tree species on the four sites to examine the relative importance of different scale and intensity in controlling stand [structure]. We found that the importance of patch dynamics varied greatly among areas.

The two Interior forests showed a strong contrast in the scale, frequency and type of disturbance. The forest at Adams Lake showed no evidence of major disturbance in the past 400 years and individual tree death appeared to be the main process of gap formation. In contrast, the forest at Damfino Creek originated about 330 years ago. The presence of a single cohort of pine dating from *c.* 1660 suggests that a fire destroyed the previous forest. Outbreaks of the defoliator, two-year cycle spruce budworm (*Choristoneura biennis*) has had major impacts on tree growth, mortality and gap processes."

"There appears to exist a continuum of disturbance that ranges from frequent stand destroying events in which the post destruction cohort is never replaced to rare disturbance in which replacement follows after individual tree death."

Parish, R. and J.A. Antos. 2002. Dynamics of an old-growth, fire-initiated, subalpine forest in southern interior British Columbia: tree-ring reconstruction of 2 year cycle spruce budworm outbreaks. Can. J. For. Res. 32(11):1947–1960.
www.nrcresearchpress.com/doi/abs/10.1139/x02-132
"Tree-ring width chronologies of three species from a 330-year-old subalpine forest were used to reconstruct outbreaks of 2 year cycle spruce budworm (*Choristoneura biennis* Freeman). The growth of host species, Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), was compared with that of the nonhost, lodgepole pine (*Pinus contorta* Dougl. ex Loud.) with and without the removal of the effects of climate on growth. Seven periods, 1989–1991, 1943–1957, 1911–1927, 1869–1875, 1839–1861, 1823–1829, 1785–1801, were identified in which the growth of both host species was reduced relative to the non-host; this includes the single known outbreak from 1944 to 1956. Spectral analysis indicated a periodicity for growth reduction of the host relative to non-host species of ca. 45 years for both spruce and fir. For three periods, the known outbreak in the 1940–1950s, and two inferred outbreaks in the 1910–1920s and 1840–1850s, we calculated the four measures of radial growth first proposed by Brubaker and Greene (L.B. Brubaker and S.K. Greene. 1979. Can. J. For. Res. 9: 95–105): the maximum rate of growth loss, 1-year and 5-year losses, and the rate and time to recovery. Growth losses were greater for fir than for spruce during all three periods. During the 1940–1950s, growth losses were severe, but losses were less in the 1910–1920s. The impact of *C. biennis* has varied among outbreak periods but, overall, has made a pronounced contribution to present stand conditions. Our work suggests that budworms have been a frequent agent of disturbance with major effects on forest dynamics in southern British Columbia, especially in spruce–fir forests when long periods occur between fires."

Parish, R., J.A. Antos, and M.-J. Fortin. 1999. Stand development in an old-growth subalpine forest in southern interior British Columbia. Can. J. For. Res. 29(9):1347–1356.
www.nrcresearchpress.com/doi/abs/10.1139/x99-080
"The dynamics of an old-growth Engelmann spruce (*Picea engelmannii* Parry) – subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) forest were investigated using stand-history reconstruction. Age and size structures, tree location, and radial increment patterns were used to link establishment and growth to disturbances. The spatial distribution of trees was used to infer patterns of establishment and mortality. The forest originated in the 1650s, probably after fire. Initial establishment took almost 80 years, after which fir continued to recruit effectively, but spruce did not. The tree-ring record showed no evidence of widespread disturbance during the first 200 years, but from about 1855 to 1900 a major period of canopy mortality caused by bark beetles released suppressed trees and provided opportunities for establishment and rapid growth of seedlings of both species. Most current canopy trees estab-

lished or released during this period of disturbance; thus, many canopy trees are fairly young in this old-growth forest and canopy turnover is high. A short period of disturbance (1927–1932) caused by the balsam bark beetle (*Dryocoetes confusus* Swaine) resulted in release of suppressed trees but did not promote seedling establishment. At the time of study (1994), the stand was undergoing another minor disturbance caused by this insect. Bark beetles appear to be of fundamental importance in controlling the dynamics of spruce–fir forests during the long intervals that often occur between fires in cool, wet climates."

Parminter, J. 1987. Fire history and fire ecology of the Height-of-the-Rockies Wilderness Area. B.C. Min. For. Lands, Prot. Br., Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/docs/scv/SCV107.pdf

"The outward appearance of the forests of the ESSFa [ESSFdk] subzone and the physical traces of fire history indicate the consistent role of fire in the forests of this subzone. Post-fire regeneration times in this subzone will be longer than in the MSa [MSdk] subzone - on the order of 10 to 20 years. As was the case with the lower zone, these forests will also lose their lodgepole pine component (without further fires) and the Engelmann spruce will dominate. Subalpine fir will dominate the lower canopy in older stands and could become a significant component after the Engelmann spruce starts to die off.

Fire history in the upper elevation forests of the ESSFap [ESSFdkp] and ATf [IMA] subzones is less outwardly obvious as fire size is limited by fuel types and topography. Stands are more open and tree growth slower such that the appearance of a forest is not necessarily a good indicator of past fire history. However, it is certain that the majority of the upper elevation forests in the Height-of-the-Rockies Wilderness Area have burned at some time in their history. As environmental conditions in these subzones are the harshest the post-fire regeneration periods will be in the order of 30 to 50 years."

Parminter, J. 1993. Fire history of Bowron Lake Park. B.C. Min. For., Res. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib4291.pdf

"A 530 hectare lightning-caused fire of 1961 - the Wol - is the most obvious fire in this zone on the slope along the east side of Isaac Lake. Others from 1961 at the southern end of the lake are smaller."

"Two more recent burns in the ESSF were in 1971 on the south side of Ford Peak (the Key fire) and the other on the lower slopes of Flattop Mountain above Harold Creek (the Top fire). These burns were not regenerating as well as the 10-year older Wol fire, indicative of the slower rate of recovery of forests in the ESSF." "In the absence of fire disturbances, the upper elevation ESSF forests exhibit small scale gap processes."

Perrault, J. 2011. Spatial accumulation patterns of macroscopic charcoal in an alpine lake in British Columbia, Canada. BA Honours thesis. Carleton Univ., Dep. Geog. Environ. Stud., Ottawa, Ont.

Pollack, J., H. Quesnel, C. Hauk, and H. MacLean. 1997. A quantitative evaluation of natural age class distributions and stand replacement intervals in the Nelson Forest Region. Vol. 1. B.C. Min. For., Nelson For. Reg., Nelson, B.C. Tech. Rep. TR-015.
www.for.gov.bc.ca/hfd/pubs/RSI/FSP/Nelson/RNE_TR-015.htm

Using the corrected Forest Inventory Planning (FIP) age-class data, estimated stand replacement intervals ranged from 138 years for the ESSFdk, to 149 years for the ESSFdc1, to 153 years for the ESSFwm, to 170 years for the ESSFwc4, and to 221 years for the ESSFvc.

Rogeau, M.-P. 1994. Fire history mapping of Mount Assiniboine Provincial Park, British Columbia for Central Rockies Ecosystem Interagency Liaison Group, Banff, Alta.

A stand origin map was created using airphoto interpretation to identify individual stands, which were then sampled to determine fire dates through dendrochronology. Stand origin dates found for Daer Creek were 1725, 1800, 1830, 1850, and 1884; for Lachine Creek were 1485, 1745, and 1939; for North Simpson were 1440, 1560, 1630, 1650, 1695, 1720, 1894, and 1920; for South Simpson were 1640, 1655, 1660, 1700, 1755, 1800, and 1843; for Mitchell Creek were 1490, 1505, 1720, 1760, 1854, 1880, and 1922; and in the core area were 1470, 1560, and 1920.

Rogeau, M.-P. 2000. Fire regime analysis, Mount Revelstoke National Park. Prepared for Parks Canada, Revelstoke, B.C. Unpubl. rep.
www.for.gov.bc.ca/HFD/library/documents/Rogeau_2000.pdf

"...field data collection, coupled with the information gained from the stand origin modeling, demonstrated that the level of fire activity was historically high. Mean-fire-return-intervals for MRNP ranged from 18 to 48 years in the last 200 years, while the stand origin modelling exercise estimated a mean fire cycle of 266 years for the Greater MRNP...." The ESSF biogeoclimatic zone covers 42 364 ha of the total forested area of 93 754 ha and has an average fire cycle of 145 years.

Rogeau, M.-P. 2003. Fire risk of environmentally sensitive sites, Mount Revelstoke and Glacier National Parks – BC, part 1: fire regime analysis of greater MRGNP. Prepared for Parks Canada, Revelstoke, B.C. Unpubl. rep.
www.for.gov.bc.ca/HFD/library/documents/Rogeau_2003.pdf

"The total area burned for both Mount Revelstoke and Glacier National Parks since 1960 amounts to 6,151 ha. This represents a burn rate of 140 ha / year, or 0.19% of the forested area. The Ecological Land Classification of the Parks (Achuff et al. 1984) estimate that 54% of the land is composed of rock and ice, 19% of ICH forest type and 27% of ESSF forest type. This rate of disturbance, for a forested area estimated to be 74,014 ha, is equivalent to a 529 year fire cycle. Since 80% of fires are caused by lightning, it is believed that this fire cycle is much longer than the historical one when no fire suppression was taking place.

Interestingly, despite the fact that the Greater Area sees 55% more fires than the parks, its fire cycle is longer. The total area burned for the Greater Area since 1950 amounts to 58,130 ha. This represents 1,077 ha burned per year or a rate of disturbance of 0.16% of the forested area. This is equivalent to a 643 year fire cycle."

Spilsbury, R.H. and E.W. Tisdale. 1944. Soil-plant relationships and vertical zonation in the Southern Interior of British Columbia. Scientific Agric. 24(9):395–436.

Above Tranquille, B.C. repeated fires have favoured lodgepole pine, while Engelmann spruce and subalpine fir have nearly been eliminated. Forb-dominated treeless openings in the upper ESSF zone contain remnants of charred wood, indicating previous forest cover.

Steele, C. 2010. Fire and climate interactions during the past 1000 years from the West Kootenay District, British Columbia, Canada. BSc Honours thesis. Carleton Univ., Dep. Geog. Environ. Stud., Ottawa, Ont.

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"Wildfires have been relatively infrequent, especially in the Quesnel Highland portion of the ESSF, and young forests are much less common than in most other biogeoclimatic units of the Region."

"The ESSFxv1 includes the highest-elevation forests on the leeward slopes of the Coast Mountains west of Taseko Lakes. It extends from Anvil Mountain west to Tweedsmuir Park and also occurs in the Itcha and Ilgachuz mountains." "Subalpine fir and Engelmann spruce are climax species but, due to past wildfires and slow rates of succession in this cold, dry climate, most natural mature stands are dominated by lodgepole pine."

Steventon, D. 1997. Historic disturbance rates for interior biogeoclimatic subzones of the Prince Rupert Forest Region. B.C. Min. For., Prince Rupert For. Region, Smithers, B.C. Exten. Note 26.
www.for.gov.bc.ca/rni/research/Extension_notes/Enote26.pdf

"One important parameter of natural disturbance regimes is the frequency at which stand initiating events such as severe fire have historically occurred, and how this has shaped the age structure of forest landscapes. In this note, using the forest inventory database, I examine the historic rate of stand initiating disturbances in the SBPSmc, SBSdk/mc and ESSFmc/wk/mk Biogeoclimatic (BEC) subzones of the Lakes, Morice and Bulkley forest districts, Prince Rupert Forest Region."

Stand-initiating disturbance rates were calculated using all age data and then truncated age data, which account for possible biases in assigning ages to stands older than 160 years. Results were as follows: SBPSmc: 91 and 92 years; SBSdk: 93 and 95 years; SBSmc: 124 and 148 years; ESSFmc: 166 and 284 years; ESSFmk: 337 and 810 years; and ESSFwv: 220 and 1150 years (for all age data and truncated data, respectively). The considerable differences for the last two ESSF subzones are due to the large areas of stands older than 240 years for which the true ages are not known.

Thompson, R.D. 2005. Fine-scale disturbance and stand dynamics in mature, spruce-subalpine fir forests of central British Columbia. MSc thesis. Univ. Northern British Columbia, Nat. Resourc. Environ. Stud., Prince George, B.C.

www.collectionscanada.gc.ca/obj/thesescanada/vol2/002/MR28390.pdf

"Fine-scale disturbance and stand dynamics within mature, spruce-subalpine fir forests were compared and contrasted across the central interior of British Columbia. The central interior is ideal for the study of fine-scale disturbance because sub-boreal and subalpine ecosystems span the dry interior plateau and grade eastward into the progressively wetter, cooler, high-elevation ecosystems of the Rocky Mountain Foothills. Three biogeoclimatic variants where selected across this climatic gradient: the dry-warm Sub-Boreal Spruce (SBSdw3), the wet-cool Sub-Boreal Spruce (SBSwk1), and the wet-cool Engelmann Spruce-Subalpine Fir (ESSFwk2). Traditional and newly developed dendroecological techniques were used to identify the effects of past intermediate- and coarse-scale disturbance events, and to infer regional climate fluctuations, in order to separate these from the effects of fine-scale disturbance. Periods of canopy mortality occurred in the ESSFwk1 variant during the 1710s and 1830s, in the SBSwk1 variant during the 1830s and 1870s, and in the SBSdw3 variant during the 1870s. Based on historical documentation and dendroecological evidence, these periods of canopy mortality were likely caused by spruce beetle, and there is strong evidence of notable shifts in species composition.

A western balsam bark beetle outbreak occurred in the ESSFwk2 variant during the 1920s and 1930s, and tree ring analyse provides strong evidence that species dominance shifted from subalpine fir to spruce within these stands. Moran's I analysis of canopy ascension dates suggests that fine-scale disturbance is random in space and time across all ecological variants. Canopy openings caused by disturbance averaged ~2.5 m in diameter, which is equivalent to the average distances between nearest neighbours. Decadal disturbance rates did not differ by variant ($p = 0.117$) or by species nested within variant ($p = 0.418$). Although the decadal disturbance rates did not differ by variant, mean rates within SBSdw3, SBSwk1, ESSFwk2 variants were 7.4, 6.4 and 5.0%, respectively. The results of this research indicate that fine-scale disturbances are important ecological processes in sub-boreal and subalpine forest ecosystems. Within these ecosystems, however, there is considerable overlap between disturbance types of varying spatial and temporal scales. Intermediate- and coarse-scale disturbance events, such as those caused by insects (e.g., spruce beetle and western balsam bark beetle), have been more influential in causing distinct changes in stand structure and composition than fine-scale disturbances. Consideration of disturbance events at multiple scales, however, shows that fine-scale disturbance does exhibit continuous stand level maintenance and renewal."

Tymstra, C. 1988. Fire history report, volume 1 – an historical review of wildland fires in Yoho National Park. Yoho Natl. Park, Resourc. Conserv., Field, B.C.

"This report summarizes the historical documentation of past fires in and adjacent to Yoho National Park from 1880 to present. A brief discussion of native use and fire before 1880 is also included."

"The majority of the forested vegetation in Yoho national park has been subject to fire. Early (i.e. less than 50 years) post-fire successional stands are however, rare. Most of the present low elevation forests originated from fires in 1883, 1887, 1889, 1904, 1914 and 1926. As a result, advanced successional stands of lodgepole pine mixed with white spruce and fir are relatively common."

"From a fire management perspective, the evidence available suggests that the historic fire regime (and hence its effects) within Yoho national park was not significantly altered by the activities of early man (i.e. natives). Before 1880, lightning was the predominant cause of forest fires." Between 1910 and 1987, 240 wildfires burned at least 10 584 ha in the park. Peak decades were 1920–1929 with 3921 ha burned and 1970–1979 with 4682 ha burned. During the other decades, the area burned ranged from 6 to 821 ha and averaged 330 ha.

Tymstra, C. 1991. Fire history of Yoho National Park, British Columbia and implications for fire management. MSc thesis. Univ. Alberta, Dep. For. Sci., Edmonton, Alta.

"Since deglaciation began, over 10,000 years ago, fire has had a continued and ecologically significant role in influencing the development and perpetuation of forest communities within and adjacent to Yoho National Park. The unadjusted fire cycle for the whole of Yoho National Park in the last half millennium is 132 years. The western portion of the park has had the greatest incidence of fire and the greatest area burned. The differences in the fire cycles between eastern (FC = 239 years) and western (FC = 105 years) portions of the park are a function of the distance from the Continental Divide. Prior periods of drought and high surface winds were common factors associated with the large, high intensity fires that occurred during the 1910-1988 period. Within Yoho, different types and sizes of fires have resulted in varying fire effects. The fire regime is however, predominantly characterized by large, high intensity fires."

Van Wagner, C.E., M.A. Finney, and M. Heathcott. 2006. Historical fire cycles in the Canadian Rocky Mountain Parks. For. Sci. 52(6):704–717. www.ingentaconnect.com/content/saf/fs/2006/00000052/00000006/art00009

"The subject of this article is the fire history of seven contiguous national and provincial parks in the Canadian Rocky Mountains, four to the east of the continental divide and three to the west. Seven centuries of time-since-fire data were combined and arrayed in three sets: all seven parks together, then the east-side and west-side groups separately. Fire cycles were estimated by four different methods: two of them statistical and two deterministic. Statistical evidence of distinct changes in fire regime, always toward a lower burning rate, was uncovered, with transitions in 1760 and 1940 on the east side, and in 1840 on the west side. The principal conclusions were: the seven parks as a unit supported a fire cycle of 60–70 yr for nearly five centuries before 1760. The burning rate then dropped sharply and a longer cycle of about 175 yr prevailed until 1940. Fire history in the combined large parks on the east side was similar to the above. By contrast, the smaller west-side parks group sustained a fire cycle of about 90 yr for at least five centuries before 1840; the burning rate then decreased irregularly to 2000. On the east side, the near absence of burned area after 1940 was attributed to the onset of effective fire protection. Possible prior causes of the earlier transitions on east and west sides include changes in climate or aboriginal fire practices, but this issue is left unresolved."

Vasbinder, W.J. 2001. Forest fire in the mountain ranges of northeastern British Columbia: a historical perspective. MSc thesis. Univ. Northern British Columbia, Nat. Resourc. Manag., Prince George, B.C.

"In an effort to sustain biological diversity, it has been proposed that the impacts of forest management approximate the effects of natural disturbances. This study has investigated mountainous sub-boreal spruce (SBSvk) and Engelmann spruce–subalpine fir (ESSFwk2/wc3) biogeoclimatic units in north-eastern British Columbia in an effort to provide information on historical fire regimes. This information may help in the development of forest management plans that better approximate ecological processes. The influence of topography on the spatial and temporal extent of seral age-class patches and contemporary lightning-caused fires was a primary focus in this study.

Natural disturbance patch characteristics were described and estimates were calculated of the periodicity of stand-initiating disturbances. A digital elevation model was constructed for the study area and related to age-class information derived from forest cover data, as well as lightning-caused fire location data for the period of 1950–1992.

Results showed strong spatial differences in natural disturbance patch characteristics based on landscape orientation. Patch characteristics for both eastern and western slopes of the Rocky Mountains indicated that current estimates of patch size distributions and the periodicity of stand-replacing disturbances do not well approximate historical landscape patterns for the 100 year period prior to 1950. Topography was revealed to have a strong relationship with age-class patch size on western slopes, but it was only weakly correlated with other patch characteristics on western and eastern slopes. The topographical associations of lightning-caused fires and seral patches were somewhat similar, but could not provide conclusive evidence that fires initiated younger forest patches. The dominance of old-growth forest age-classes in the study landscape provided support for the importance of fine-scale or non-stand replacing natural disturbances in the maintenance of forest structure and composition. Explicit consideration of landscape characteristics is recommended in future attempts to approximate natural disturbances."

Vasbinder, W., B.C. Hawkes, and C. Opio. 1998. Influence of topography upon the historical fire regime of the SBSvk and ESSFwk2/wc2 biogeoclimatic subzones, British Columbia. In: Ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. Workshop proc. M. Jull, D. Coxson, S. Stevenson, D. Lousier, and M. Walters (editors). UNBC Press, Prince George, B.C., p.18. http://web.unbc.ca/~wetbelt/docs/1997-Wetbelt-Workshop-Proceedings.pdf

"A retrospective study of fire was initiated in the north-eastern interior of British Columbia as a part of the McGregor Model Forest's larger effort to determine the ecological processes that influence the forest landscape in this area. This study seeks to define and quantify historical disturbance patch size, pattern, and frequency in the SBSvk and ESSFwk2/wc3 biogeoclimatic subzones, and to evaluate the influence of topography upon these elements of the fire regime."

"The study area encompasses approximately 1.3 million hectares of forested and mountainous terrain stretching along the western side of the Rocky Mountains from McBride, BC in the southeast to Pine Pass in the northwest, and an area of the eastern slopes and foothills which extends north-east to the vicinity of Chetwynd, BC. British Columbia Ministry of Forests digital forest inventory data is being heavily relied upon to determine the age and patch characteristics of the study landscape." "Preliminary results indicate that the fire cycle for these cool and wet mountain subzones seems to be longer than initially estimated. The fire cycle for these areas could be as long as 560–700 years. Disturbance patch sizes for the study area are small, with 51% of disturbance patches 1–9 ha in size. Patch size seems to exhibit a north-south gradient over the study area with the northern half of the study area characterized by larger areas of disturbance than the southern half of the study area. It appears that northern patch size results are being influenced by the much larger disturbance patches found on the east slopes of the Rocky Mountains."

Zeglen, S. 2002. Whitebark pine and white pine blister rust in British Columbia, Canada. Can. J. For. Res. 32(7):1265–1274.
www.nrcresearchpress.com/doi/abs/10.1139/x02-049

"A survey of the health of whitebark pine (*Pinus albicaulis* Engelm.) was conducted throughout its range in British Columbia, Canada. Over 3 years, 24 070 trees were examined for mortality, incidence of white pine blister rust (*Cronartium ribicola* J.C. Fisch.), or other damage. About 19% of whitebark pine (>1.3 m in height) were dead, and another 31% had active blister rust infections. Tests of relationships between the proportion of healthy, infected, or dead trees and elevation, latitude, and longitude produced mixed results. The ratio of healthy to infected whitebark pine varies considerably across the province, with a trend of increasing incidence from west to east. Losses to mountain pine beetle (*Dendroctonus ponderosae* Hopkins) proved minor, but bark stripping by mammals was common. Whitebark pine seedlings (<1.3 m in height) revealed lower rates of mortality (11%) and rust infection (4%) than larger trees. However, the pioneer species whitebark pine was found in less than half the regeneration plots and was usually outnumbered by subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). The combination of mature tree mortality, lack of suitable substrate for regeneration, and the incursion of climax species indicates a continued decline in whitebark pine populations in British Columbia."

Arsenault, A. 1997. Comparison of the patterns of natural disturbances and harvesting and their impact on stand structure and dynamics in coastal and interior cedar-hemlock forests. For. Renewal BC, Res. Program. B.C. Min. For., Kamloops For. Reg., Kamloops, B.C.
www.for.gov.bc.ca/HFD/library/Frbc1997/frbc1997mr159.pdf

Wildfires of the past century seem to be more important in the southern portion of Wells Gray Provincial Park (in the ICHmw3) and large fires on plateau-like terrain occurred around 1700, 1890, 1925 and 1926. Unburned remnants of old-growth forests within large burns are associated with topography and wetter sites and range in size from 1 to 2 ha and greater. Fires on the valley bottoms, lower slopes and middle slopes of the upper Clearwater Valley resulted from mixed-severity and stand-replacing fire regimes. Sites near Phillips Creek also burned during the 1926 fire while the remaining sites studied consisted of mature forests (70–100 years old) interspersed with older forests (150–430 years old). At Oliver Creek (in the ICHwk1 and ICHvk1) most sites had evidence of fire history, with fires occurring 30, 60, 100, and 400 years ago. The valley floor and middle slopes have different seral stage distributions and snow avalanches are also important influences in this regard.

Arsenault. A. 1998. Disturbance ecology in forests of the Interior Cedar-Hemlock Zone. In: Ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. Workshop proc. M. Jull, D. Coxson, S. Stevenson, D. Lousier, and M. Walters (editors). UNBC Press, Prince George, B.C., pp. 16–17.
http://web.unbc.ca/~wetbelt/docs/1997-Wetbelt-Workshop-Proceedings.pdf

"A study investigating disturbance ecology and its implication in forest management was conducted in ICH forests of the Kamloops Forest Region during 1995 and 1996. Three biogeoclimatic variants, the ICHmw3, ICHwk1 and the ICHvk1, were examined in Wells Gray Provincial Park, as well as in the valleys of the Mad, Upper Adams and Upper Seymour rivers."

"In young forests (ca. 70 yr) *Armillaria ostoyae* was the dominant mode of mortality associated with small-scale disturbances. Although this pathogen was present on all conifer trees of all sizes it appeared to cause less mortality in western red cedar. Furthermore an examination of gapmakers vs. gapfillers showed a strong successional shift towards a potential dominance of western red cedar illustrating how important pathogens are important in driving succession in this ecosystem. Although pests were not significant in causing gaps intersected by our transects, the western hemlock looper and the spruce bark beetle are known to be important mortality agents in sections of our study area. Wind and or heavy snow-load were also important mode of mortality uprooting and snapping trees. Heavy winds can also produce larger disturbances like the windstorm we experienced in Wells Gray Provincial Park on August 30th. 1996 which created many blowdown patches of different sizes totalling several hundred hectares in less than 30 minutes.

At the landscape level fire is the dominant large-scale disturbance in the Interior Cedar–Hemlock Zone. In Wells Gray Provincial Park fires in the last hundred years appear to have been more important in the southern section of the park corresponding with the warmer portions of the ICH. The fires around 1926, 1890 and 1700 burned large sections of forests occurring on plateau-like terrain. Examination of air photos and field surveys have revealed that often amongst these large burns are some small unburned pockets of older forests. These old forest patches vary in size but are often quite small 1–2 ha and were not recognized on the fire maps. Remnant forest patches examined were often linked with wetter site conditions related to topographic position (i.e. toe position, depressions, canyons), fine soil texture, and spray zones of waterfalls.

Although it is likely that other old-growth forest remnant have been left by chance, the link we found between small old-growth remnant patches and site condition is undeniable and has important implications for landscape unit planning and conservation biology. Although fire is still a dominant force in the wetter portions of the ICH both fire history maps and the relative proportion of forests older than 250 years suggest much lower fire frequencies in the ICHwk1 and ICHvk1 than in the ICHmw3."

Arsenault, A. and T. Goward. 2000. Ecological characteristics of inland rain forests. In: Proc. conf. on the biology and management of species and habitats at risk. Feb. 15–19, 1999, Kamloops, B.C. Volume One. L.M. Darling (editor). B.C. Min. Environ., Lands and Parks, Victoria, B.C. and Univ. College of the Cariboo, Kamloops, B.C., pp. 437–439.
www.env.gov.bc.ca/wld/documents/ie08arsenault1.pdf

"Dominated at maturity by western redcedar and western hemlock, inland rain forests closely resemble coastal temperate rain forests in the complexity of their architecture, and the lushness of their understories. They differ, however, in their respective disturbance regimes and regeneration dynamics. Although rain forests as a whole are characterized by a low frequency of catastrophic disturbance, inland rain forests are proportionately much more susceptible than coastal rain forests to fire, wind, insects, and avalanches.

Related to this, the age-class structure of inland rain forest landscapes is somewhat less weighted to old growth, and even less to 'antique' forests, that is, forests that have escaped catastrophic disturbance for a period longer than the age of the oldest trees within them."

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 26.
www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh26.htm

"Fire has had a major influence on vegetation development in the ICH. Seral (nonclimax) stands of lodgepole pine, trembling aspen, paper birch, spruce, subalpine fir, and black cottonwood often dominate at lower elevations. Even older stands, approaching climax, usually contain remnant individuals of shade-intolerant species that established after a fire. Except in sheltered middle-elevation valleys, on some north-facing slopes, and in the

Meziadin – Bell-Irving area, it is difficult to find a stand in the ICH that has not been disturbed by fire within the past few centuries."

Beck, J. 1984. Fire history and range enhancement study for the Cayuse Creek area. Selkirk College. Castlegar, B.C. Wildland Recreation Tech. Rep. (student pap.).

The surface fire periodicity for a seral ponderosa pine stand in the ICHdw near Deer Park (38 km northwest of Castlegar on Lower Arrow Lake) was 11.6 years between 1762 and 1937.

Braumandl, T.F. and M.P. Curran (compilers and editors). 2002. A field guide for site identification and interpretation for the Nelson Forest Region: Part 2. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 20. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh20.htm

"The ICHxw is present from mid slope to valley floors in the Pend d'Oreille Valley and on western and southern exposures and valley floors from Boswell to Kitchener (east of Creston)." "The ICHxw has very few climax stands due to frequent wildfires. Douglas-fir is the dominant tree species; Py [ponderosa pine] and Lw [western larch] are also common; Cw [western redcedar], Bg [grand fir], and rarely, Hw [western hemlock] are found on mesic or wetter sites; Pl [lodgepole pine] and Pw [western white pine] are less common seral species." "Fire and the abandonment of farm fields, has resulted in extensive shrub fields and mixed Fd/Py [Douglas-fir/ponderosa pine] stands."

The ICHdw is found in the "southern Monashee, Selkirk, and Purcell mountains; restricted to valley bottoms and lower slopes of the Upper Granby river; Christina Lake; Lower Arrow Lake, north to Fauquier; Columbia River, Slocan Valley, north to New Denver; Kootenay Valley, north to Kaslo; Goat River and southern Moyie River below the ICHmw2." "Fire origin stands of Fd and Lw are very common. Many of these stands originated around the turn of the century after fires set by miners. As a result of these fires and logging, very few climax or old-growth stands exist." "The major role of fire in the ICHdw has resulted in scattered old-growth Py stands."

The ICHmk1 is located in "valley bottoms or areas of moderate relief between ICHmw1, ICHmw2, or ICHdw and subzones of the Dry Climatic Region. The ICHmk1 occurs in the Rocky Mountains along the Lower Bull, Lower Elk River, Upper Kootenay, Beaverfoot, and Kickinghorse rivers; in the Rocky Mountain Trench between the Spillimacheen and Blaeberry rivers; in the southern Purcell Mountains along the St. Mary, Moyie, and Yahk rivers; and in the southern Monashee Mountains within the Kettle and Granby River drainages." "The ICHmk1 has been extensively disturbed by wildfires, so climax stands are rare. Seral stands with Pl are common. These stands have extensive mountain pine beetle history."

The ICHmw1 occupies "mid to lower elevations in the Rocky Mountains from the Kickinghorse to the Sullivan river, and northern Selkirk Mountains from Parson to Gold River." "Moderate fire return periods have led to a mosaic of climax and seral stands."

The ICHmw2 is found in the "southern Monashee, Selkirk, and Purcell mountains; valley bottoms and mid to lower slopes of Upper Arrow Lake, Trout Lake, Lardeau River, and upper St. Mary's River valleys; mid-slope positions above the ICHdw in the upper Granby river, Lower Arrow Lake, Columbia River, Slocan Valley, Kootenay Valley, Goat River, and southern Moyie river." "Recurrent fires have led to a mosaic of climax and seral stands." "These forests historically supported an old-growth dependent wildlife community, where fire had not affected the forest extensively."

The ICHwk1 "is found from valley bottoms to mid slopes in the upper Duncan, Incomapleux, Akolkolex, Illecillewaet, and Gold rivers and upper Pingston Creek, along the Revelstoke Reservoir north to the Goldstream River and the Mica Reservoir, north of Smith Creek." "The rarity of wildfire has led to the occurrence of numerous old-growth Cw and Hw stands. Prolific growth of the mixed shrub or fern vegetation complexes may occur on zonal and wetter sites after harvest." "The extensive old-growth forest has historically supported an old-growth dependent wildlife community."

The ICHvk1 occupies "valley bottom and lower slopes in the northern Selkirk and Monashee mountains, north of the Goldstream River to Mica Creek. Upper ends of Downie and Kirkup creeks and Jordan, Wolsey, and Tangiers rivers." "Due to the rarity of wildfires, climax old-growth stands of Cw and Hw are abundant. Windthrow, insects, and disease are the major natural disturbances. Prolific growth of the mixed shrubs or fern vegetation complexes commonly occurs on zonal and wetter sites after harvest." "Extensive old-growth forests support a range of old-growth dependent species."

Daniels, L.D., J. Cochrane, and R.W. Gray. 2006. Refining mixed-severity fire regimes in the Rocky Mountain Forest District. Prepared for Tembec Inc., Cranbrook, B.C.; Can. For. Products Ltd., Radium Hot Springs, B.C.; and For. Investment Account, Victoria, B.C.
www.trench-er.com/public/library/files/mixed-severity-fire-regimes.pdf

"We have used tree rings to reconstruct the fire history of 10 stands dominated by large-diameter western larch, Douglas-fir, and ponderosa pine trees. All study sites were in the Montane Spruce (MS) and Interior Cedar Hemlock (ICH) biogeoclimatic zones in the Rocky Mountain Forest District. Each stand was structurally complex with an upper stratum of veteran trees that were >200 years old.

We developed 13 new site-specific ring-width chronologies, six for Douglas-fir, five for western larch and two for ponderosa pine and one regional chronology for each species. These chronologies were used to visually and statistically crossdate disks with fire scars to ensure fire scar dates were accurate at an annual level of resolution. The Douglas-fir, western larch and ponderosa pine chronologies were up to 323, 355 and 515 years in length, respectively. All chronologies had significant inter-annual variation and were significantly correlated over the period from 1750–2004, indicating the common influence of regional climate.

The 77 fire scar samples from nine of the 10 study sites yielded 204 fire scars and 70 unique fire dates from 1567 to 1944. Scars were recorded at only one site for 59 of 70 fire years. Notable years in the fire record occurred in years when a large number or percent of trees were scarred and fires scarred trees at more than one site. The highest scar frequencies were in 1720 and

1889, when 60% and 28% of recorder trees were scarred at three different sites. Regional fires, fires that caused scars at two or more sites, burned in 12 years from 1652 to 1922.

For individual sites, the fire scar records ranged from 177 to 470 years and included 13 to 37 fire scars, which represented four to 14 fire intervals. The Weibull median probability intervals (WMPI) ranged from 13.8 to 32.4 years and two to 102 years separated successive fires at each site. The current fire-free intervals ranged from 61 to 121 years and generally exceed the historic range of variation for the study stands, indicating a change to the fire regime during the past century. At the regional scale, only two fires scarred trees during the 65 years from 1940 and 2004. Over the last three centuries, the highest fire frequencies and shortest intervals between fires were during the settlement era from 1870 to 1939. Prior to the 1870, mean fire intervals significantly longer than fire intervals during the settlement era, likely reflecting the influence of land use and climate variation on fire frequency.

To extrapolate results from individual stands to the surrounding landscape requires knowledge of the abundance and distribution of the forest types in which we find evidence of mixed-severity fires. Our GIS determined that structurally complex forests currently represent c. 10% of forest in the ICH and MS zones of the Invermere and Cranbrook TSAs. These results provide important background information to facilitate a statistically robust regional analysis of fire history at the landscape scale."

Daniels, L.D., Z. Gedalof, M.F.J. Pisaric, C.J.C. Mustaphi, E. Da Silva, H. Marcoux, V. Mather, J. Nesbitt, E. Paul-Limoges, J. Perrault, and C. Steele. 2011. Historic climate-fire-vegetation interactions of the West *versus* East Kootenays: implications of climate change and fire suppression. Prepared for Univ. British Columbia, Dep. Geog., Vancouver, B.C.; Carleton Univ., Dep. Geog., Ottawa, Ont.; and Univ. Guelph, Dep. Geog., Guelph, Ont. www.trench-er.com/public/library/files/kootenay-fire-report.pdf

"In western North America, wildfire is a primary disturbance driving the diversity, age structure, and dynamics of forests. In some forests, climatic warming combined with fire exclusion has created conditions conducive to catastrophic wildfires. Understanding the relationships between wildfire and environmental change is a fundamental concern, particularly in forests near the wildland-urban interface where human lives and property are at risk. In this project, we compared the fire history and forest dynamics of the Joseph-Gold Creek watersheds near Cranbrook in the East Kootenay district and remnant old forests surrounding Nelson in the West Kootenay district of southeastern British Columbia.

We used multiple lines of evidence, including charcoal in lake sediments and analysis of tree rings, to reconstruct historic fire regimes. In both the West and East Kootenay study areas, fire regimes varied significantly with steep elevational gradients. At high elevations, stand-replacing fires burned every 150-300 years according to our lake sediment, fire scar and forest age results. The lake sediment research yielded a 10,000-year fire reconstruction for high elevations (>2000 m.a.s.l.) in the West Kootenay study area. It included 36 fires, burning once every 270 years on average. Fire frequencies peaked 4,000-6,000 years ago, but 2-3 large fires burned during the past

1,000 years. There was at least one large fire in the early 1900s. Forest history reconstructions from tree rings corroborated this evidence. In the West Kootenay study area, high elevations forests established after severe fires that burned up to 340 years ago but many forests established from 1850 to the 1890s, concurrent with the gold rush and European settlement. In the East Kootenay study area, severe fires burned 100-360 years ago. A widespread fire in 1910 affected the forests at all elevations, scarring many trees, and killing even fire-resistant tree species.

In the low-elevation forests, below 1350 m.a.s.l. in the West and 1550 m.a.s.l. in the East Kootenays, there was abundant evidence of frequent, low-severity fires that burned and scarred trees once every 25 to 50 years, on average. Fires burned in late summer of drought years, often during the warm phase of the Pacific Decadal Oscillation, a climate cycle causing warm, dry conditions in the Kootenay region. Despite the historic frequency of fires and recent periods of suitable climate, these forests last burned 56 to 159 years ago. The unusually long fire-free periods are evidence of the strong effects of fire exclusion and suppression during the 20th century. The lack of recent fires was reflected in the composition of low-elevation forests in both study areas. The forest canopies were dominated by thick-barked, fire-tolerant species but subcanopy trees were shade-tolerant, thin-barked species that are susceptible to fire. Although small, the subcanopy trees were the same age as the canopy trees; they established after the last fire and did not represent continuous in-filling of the forest. Historically, the low-severity fires would have killed the smaller thin-barked trees and consumed fine fuels such as needles and branches on the ground. In absence of low-severity fires, dense forests have been perpetuated and ground fuels have accumulated. Paradoxically, by protecting the forests from low-severity fires, we have likely increased the risk of severe wildfires in the low-elevation forests surrounding Cranbrook and Nelson."

Greene, G.A. 2011. Historical fire regime of the Darkwoods: quantifying the past to plan for the future. MSc thesis. Univ. British Columbia, Dep. Geog., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/37139

"This study quantifies the fire history of the Darkwoods; a 55,000 ha property in the South Selkirk Natural Area of southeastern British Columbia, owned and managed by the Nature Conservancy of Canada. Fire scar and tree cohort chronologies from 45 plots, extending from the years 1406 – 2010, were used to determine the temporal and spatial variability of historic fires in ~4,000 ha of the southeastern-most watershed of the property, and to assess the accuracy of provincial Natural Disturbance Type (NDT) classes for the study area. In light of a mixed-severity fire regime, new and novel methods of historic fire mapping using Inverse Distance Weighting methods in a GIS were also analyzed. Using logistic regression, the spatial variation of fires at the tree- and plot-levels differed greatest by elevation, but fires at the tree-level also varied by slope steepness and slope aspect. Anthropogenic influences on the occurrence of fire over time were also evident, but only after 1945, when the occurrence of fire dropped significantly likely due to the introduction of modern methods of fire suppression in the 1940s. Results in-

dicate a mixed-severity fire regime for the study area, and the presence of numerous fire scars in mid- and high- elevation plots, in conjunction with mean fire return intervals less than 100 years, provide evidence that conflicts with provincial NDT designations. Including high-elevation stand ages, determined from increment cores, provided evidence of the absence of fire and helped refine estimates of fire boundaries, particularly in and around areas experiencing mixed- and high-severity fires. Spatial Mean Fire Intervals were longer than those calculated at the tree-, plot- and watershed-levels, reflecting the degree to which a mix of high-severity, stand-replacing fires, with low- and moderate-severity, stand-maintaining fires, can lengthen mean return intervals across a mixed-fire landscape."

Heathcott, M.J. and E.A. Johnson. 1987. Historical fires in Mount Revelstoke and Glacier National Parks: a review of existing information. Univ. Calgary, Dep. Biol. Sci. and Kananaskis Cent. Environ. Res., Calgary, Alta.

Hoggett, A. 2000. Western hemlock looper and forest disturbance in the ICHwk3 of the Robson Valley. Stage 2: the effects of western hemlock looper—report and silviculture recommendations. Univ. British Columbia, Fac. For., Vancouver, B.C.
http://wetbelt.unbc.ca/docs/Hoggett-2000.pdf

"Forest floor depth averaged 8.0 cm (SE=0.6) across all plots. Evidence of past fires in the form of forest floor charcoal was generally weak." "The majority of subplots within each plot had no readily observable charcoal within the forest floor. Only a small proportion of subplots had high levels of charcoal. Despite the low proportion of subplots with charcoal, some amount of charcoal was found in 11 of the 13 plots. This indicated that fires had occurred in the past in most, if not all, of the plots."

Holt, R.F. and M. Machmer. 2005. Development of a restoration and monitoring strategy in relation to fire effects and natural disturbances in West Arm Provincial Park. Prepared for BC Parks, Nelson, B.C.
http://veridianecological.files.wordpress.com/2010/11/westarm_veridian_finalreport.pdf

"The Dry Warm Interior Cedar – Hemlock Subzone (ICHdw) is found from the shores of the West Arm to about 1,100 m. It is characterized by very hot, moist summers and very mild winters with light snowfall and snowpacks are generally shallow to very shallow and of short duration. Major growth-limiting factors are moisture availability on drier sites and frost in some depression areas. Climax vegetation on zonal sites includes an overstory of western redcedar (Cw) and western hemlock (Hw), with an understory often including falsebox, Douglas maple, black huckleberry and baldhip rose. On cooler aspects, there tends to be an increased occurrence of Cw and Hw and high occurrence of moss in the understory. Due to the relatively high frequency fire regime of the ICHdw, most sites are occupied by seral stands dominated by species such as Douglas-fir (Fd), western larch (Lw), western white pine (Pw), lodgepole pine (Pl), paper birch (Ep) and trembling aspen (At). Drier sites are generally occupied by more fire resistant Fd, ponderosa pine (Py) and Lw, while mesic and wetter sites also include grand fir (Bg),

black cottonwood (Ac), hybrid white spruce (Sxw) and rarely (subalpine fir) Bl. This subzone has the highest tree species diversity in the province.

The Salmo Moist Warm Interior Cedar – Hemlock Variant (ICHmw4) occurs above the ICHdw on middle slopes of the park (from 1,200–1,500 m on warm aspects and 1,075–1,450 m on cool aspects) and is characterized by hot, moist summers and very mild winters with light to moderate snowfall. Moisture deficits in late summer occur occasionally on mesic and drier sites and snowpacks are generally of moderate depth and duration. Due to the relatively mild winters and significant snowpack, frozen soils are relatively rare under forested conditions. Climate is generally not growth-limiting, except for moisture availability on very dry sites and frost in some depression areas. Climax vegetation on zonal sites includes an overstory of Hw and Cw, with an understory often including falsebox, black huckleberry and Utah honeysuckle. Relatively frequent fires have created a mosaic of climax and seral stands across the ICHmw4. However, due to the extensive burning in the area associated with European settlement near the turn of the [20th] century, many sites are occupied by seral stands dominated by species such as Pl, Fd, Lw, Pw, Ep and At."

Johnson, E.A., G.I. Fryer, and M.J. Heathcott. 1990. The influence of man and climate on frequency of fire in the interior wet belt forest, British Columbia. J. Ecol. 78(2):403–412.
www.jstor.org/stable/2261120

"(1) The effects of man and climate on fire frequency have been studied using historical data and a fire-history model in Glacier National Park in British Columbia, Canada. (2) Glacier National Park experienced a change in fire cycle in the 1760s, which could be related to the occurrence of the Little Ice Age. Before 1760, the fire cycle was 80 years and after 1760 it was 110 years. The longer fire cycle after 1760 was clearly related to the cooler, moister climate which also resulted in the advance of glaciers at that time in the Park. (3) The construction of the Canadian Pacific Railroad through the Park corresponded to a period in which the area burnt by man increased (1883, 1885 and 1886) and many lightning fires occurred. There has not been a decrease in the fire frequency since the establishment of Glacier National Park in 1888, despite a fire-suppression policy. (4) Large, high-intensity, rapidly spreading fires caused by lightning are associated with a characteristic synoptic weather pattern which consists of two parts: (i) intense fuel drying associated with a stationary high-pressure system blocking access of moist Pacific air, and (ii) one or more periods of breakdown of the high-pressure system into low-pressure systems, which create lightning and high winds. (5) To have supplanted climate as a major determinant of fire frequency, man must either have used regular management burning or suppressed fires during critical weather periods. Because this has not occurred in Glacier National Park, the present fire regime is largely natural."

Lindgren, S. and K.J. Lewis. 1997. Ecological processes in the McGregor Model Forest: interactions with insects and pathogens. McGregor Model Forest Association, Prince George, B.C.
www.resourcesnorth.org/publications/
InteractionsWithInsectsAndPathogens.pdf

"The purpose of this synthesis paper is to provide a summary of the current knowledge or hypotheses regarding the interactions of insects and diseases with natural ecological processes, and to make some general interpretations with respect to ecosystem function. The development of any model that attempts to describe natural processes is difficult because of the complexity of natural systems, the interrelationships that exist between various components, and the different perspectives that result when the system is viewed at different temporal and spatial scales. For example, beetle outbreak and resultant mortality on an area when viewed over a short time period is seen to have one effect on the system, but when the same area is viewed over a time span of 300 years, the effect is seen differently. Therefore we have to be careful to define spatial and temporal scales when discussing or modelling agents of ecosystem or landscape change.

A landscape is normally thought of as a somewhat arbitrary area encompassed by a view or scenery. In the discipline of landscape ecology, the term landscape has been formalized in order to make the term useful. Thus, a landscape is an area of land, which contains a repetition of a given set of attributes. When the set of attributes change, the landscape is also changed. In the McGregor Model Forest, we are concerned with the forested landscape. The attributes of this landscape, in a retrospective context, would be a mosaic of forested areas of various ages. Each unit of this mosaic consists of a number of similar stands, with a similar successional history. Therefore, we also discuss agents of change that occur at a stand level but that affect the overall landscape."

Meidinger, D., A. McLeod, A. MacKinnon, C. DeLong, and G. Hope. 1988. A field guide for identification and interpretation of ecosystems of the Rocky Mountain Trench, Prince George Forest Region. B.C. Min. For. Lands, Res. Br., Victoria, B.C. Land Manag. Handb. 15.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh15.htm

"The ICHmc1 extends from near the southern end of Canoe Reach on McNaughton Lake to just north of McBride, at an elevation range from 710 to 1370 m. It is the driest and warmest of the ICH biogeoclimatic units in the study area." "Seral stands composed mostly of Douglas-fir, lodgepole pine, and trembling aspen are more common in this variant of the ICH than in any other for two possible reasons: the drier climate leads to drier forest fuel during summer lightning season; and a number of fires were lit during railroad construction approximately 60 years ago."

Parminter, J. 1983. Fire history and fire ecology in the Prince Rupert Forest Region. In: Prescribed fire–forest soils symp. proc. Mar. 2–3, 1982, Smithers, B.C. R.L. Trowbridge and A. Macadam (compilers and editors). B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Rep. 16, pp. 1–35.
www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Lmr016.htm

"Fire ecology knowledge is required for fire management operations as well as for other aspects of natural resource management. Natural fire has influenced ecosystem processes at various scales and has been a major factor in determining the composition and distribution of vegetation types. Different fire types and frequencies can be classed into fire regimes and these regimes related to the role of fire in different ecosystems.

Forest tree species and other vegetation possess varying degrees of fire tolerance and fire adaptations, or indeed may be totally dependent on fire for their continued existence. On the other hand certain vegetation species are fire sensitive and may be removed altogether or lessened in numbers by fire. It appears that fire has played a diverse role in the biogeoclimatic zones of the Prince Rupert Forest Region – from very rare in the Coastal – Cedars – Pine – Hemlock to very common in the Boreal White and Black Spruce. Post-fire vegetation development can follow one of several directions, the direction taken is determined by site characteristics, the nature of the fire, and subsequent environmental conditions.

Significant differences may exist between the natural fire regime and historical fire effects and the fire regime and fire effects imposed by man and his various land management activities. Guidance in the artificial application of fire can be obtained from a knowledge of the natural place of fire in the ecosystem in question."

"The ICH occupies the lower to middle elevations of the Hazelton and Skeena Mountains, the Nass River basin, and the lower Iskut River valley. Winters are cool and wet, while summers are warm and dry. Climax stands consist of a spruce hybrid (white × Sitka), western hemlock, western redcedar, and subalpine fir. Fire-originated seral stands of lodgepole pine, trembling aspen, and birch may also be found." Lightning-caused fires are common in the ICH. The Iskut wildfire of 1958 covered 31 600 ha, indicating the potential for large fires during extreme droughts.

Parminter, J. 1993. Fire history of Bowron Lake Park. B.C. Min. For., Res. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib4291.pdf

"Continuing southward from the 1898 fire in the SBS zone, which likely spills over into the ICH, are found large fires from 1905, another dating to around 1850 and another from 1749." "Although charcoal was found on the west side of Isaac Lake, on the cooler and wetter north-east aspects, there is minimal outward evidence of fire here at the landscape level."

"While it is certain that fires have burned these forests, the fire frequency is long enough that the stands reach old age and tend to look rather homogeneous in spite of having originated after different fire events." "The most prominent fire-origin stands in the ICH are south of Betty Wendle Creek, where two fire events date to 1930 and somewhere between 1850 and 1750."

Pollack, J., H. Quesnel, C. Hauk, and H. MacLean. 1997. A quantitative evaluation of natural age class distributions and stand replacement intervals in the Nelson Forest Region. Vol. 1. B.C. Min. For., Nelson For. Reg., Nelson, B.C. Tech. Rep. TR-015.
www.for.gov.bc.ca/hfd/pubs/RSI/FSP/Nelson/RNE_TR-015.htm
Using the corrected Forest Inventory Planning (FIP) age-class data, estimated stand replacement intervals ranged from 101 years in the dry ICHdw and ICHmk1, to 129 years in the ICHmw2, and to 226 years in the wet ICHwk1.

Quesnel, H. and H. Pinnell. 2000. Application of natural disturbance processes to a landscape plan: the dry warm Interior Cedar – Hemlock Subzone (ICHdw) near Kootenay Lake, British Columbia. In: Ecosystem management of forested landscapes: directions and implementation. Papers from the conference on Ecosystem Management of Forested Landscapes. Oct. 26–28, 1998, Nelson, B.C. R.G. D'Eon, J.F. Johnson, and E.A. Ferguson (editors). UBC Press, Vancouver, B.C., pp. 238–269.
"Literature review and detailed stand sampling were used to revise and update information on natural disturbances, stand types, and structural objectives for a landscape plan in the West Arm Demonstration Forest of southeast British Columbia. The driest sites of the dry warm Interior Cedar – Hemlock subzone (ICHdw) have not had stand-replacement fires for at least 244 to 319 years. Stand-maintaining fires occurred until a century ago and were followed by establishment of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), and lodgepole pine (*Pinus contorta* Dougl. ex Loud.). The fire-free period has yielded higher density stands of mid to late seral species. A third site in the ICHdw had almost complete stand-replacement fire just over a century ago. All of these stands now have greater tree species diversity, lodgepole pine mortality resulting from an interaction between root disease and mountain pine beetle (*Dendroctonus ponderosae* Hopkins), and Douglas-fir affected by root disease and Douglas-fir beetles (*Dentroctonus pseudotsugae* Hopkins). Root disease is usually present at low levels in these stands. The natural disturbance patterns and stand structural objectives used in a Total Resource Design should be modified. Underburning or other disturbances that mimic low intensity fires are desirable for maintaining ponderosa pine and western larch (*Larix occidentalis* Nutt.) in the ICHdw. Managers in this subzone can best address forest health problems by managing for more open stands of ponderosa pine, western larch, and Douglas-fir."

Rogeau, M.-P. 2000. Fire regime analysis, Mount Revelstoke National Park. Prepared for Parks Canada, Revelstoke, B.C. Unpubl. rep.
www.for.gov.bc.ca/HFD/library/documents/Rogeau_2000.pdf
"...field data collection, coupled with the information gained from the stand origin modeling, demonstrated that the level of fire activity was historically high. Mean-fire-return-intervals for MRNP ranged from 18 to 48 years in the last 200 years, while the stand origin modelling exercise estimated a mean fire cycle of 266 years for the Greater MRNP, with cycles varying spatially from 102 years for the Illecillewaet basin to 181 years for ICH forests."

The ICH biogeoclimatic zone covers 43 511 ha of the total forested area of 93 754 ha.

Rogeau, M.-P. 2003. Fire risk of environmentally sensitive sites, Mount Revelstoke and Glacier National Parks – BC, part 1: fire regime analysis of greater MRGNP. Prepared for Parks Canada, Revelstoke, B.C. Unpubl. rep. www.for.gov.bc.ca/HFD/library/documents/Rogeau_2003.pdf

"The total area burned for both Mount Revelstoke and Glacier National Parks since 1960 amounts to 6,151 ha. This represents a burn rate of 140 ha / year, or 0.19% of the forested area. The Ecological Land Classification of the Parks (Achuff et al. 1984) estimate that 54% of the land is composed of rock and ice, 19% of ICH forest type and 27% of ESSF forest type. This rate of disturbance, for a forested area estimated to be 74,014 ha, is equivalent to a 529 year fire cycle. Since 80% of fires are caused by lightning, it is believed that this fire cycle is much longer than the historical one when no fire suppression was taking place.

Interestingly, despite the fact that the Greater Area sees 55% more fires than the parks, its fire cycle is longer. The total area burned for the Greater Area since 1950 amounts to 58,130 ha. This represents 1,077 ha burned per year or a rate of disturbance of 0.16% of the forested area. This is equivalent to a 643 year fire cycle."

Sanborn, P. 2003. Natural disturbance history in the ICHwk3: fire and the prehistoric record of slope processes. For. Innovation and Investment For. Res. Program.
www.for.gov.bc.ca/hfd/library/FIA/2003/R02-19a.pdf

"Increased public interest in the management and conservation of the northern Interior Cedar-Hemlock biogeoclimatic zone requires a better understanding of disturbance regimes, and in particular, the role of infrequent but severe stand-destroying fires. In the Rocky Mountain Trench, geomorphic processes have created a particularly rich record of Holocene fires in the form of charcoal buried in colluvial and alluvial fans derived from dissected glaciolacustrine terraces in the lower Morkill River valley of the Robson Valley Forest District.

Radiocarbon dating of these charred wood and forest floor materials has yielded dates up to 8500 BP (before present), indicating that wildfires have been an important disturbance agent throughout the Holocene, with recurrence intervals of perhaps 500 - 1000 years.

Complex soil profiles in these colluvial and alluvial fan settings frequently included stacked multiple charcoal-bearing strata, which were usually laterally discontinuous, with overlapping age ranges. Observation of modern fire-triggered slope failures suggested mechanisms for formation of such deposits, and have provided criteria for distinguishing *in situ* from transported charred horizons.

In these glaciolacustrine landscapes, the lower-energy environment of colluvial toeslopes appears to be more suitable than alluvial fans for creating and preserving such records. Similar dissected glaciolacustrine landforms occur in several other major valleys in the western slopes of the Rocky Mountains, so this technique has potential for much wider application.

Land managers need to recognize that wildfire has been an important disturbance agent in this portion of the ICHwk3 throughout postglacial time. Therefore, silviculturists should not exclude prescribed fire as a management tool, and managers of protected areas should consider this historical perspective when developing policies for responding to wildfires."

Sanborn, P., M. Geertsema, A.J.T. Jull, and B. Hawkes. 2006. Soil and sedimentary charcoal evidence for Holocene forest fires in an inland temperate rainforest, east-central British Columbia, Canada. The Holocene 16(3):415–427.
http://wetbelt.unbc.ca/docs/Sanborn-et-al-Holocene-2006.pdf

"Accelerator radiocarbon dating of 147 charcoal samples recovered from colluvial and alluvial fan deposits at 29 sites was used to reconstruct the Holocene fire history of an inland temperate rainforest watershed in east-central British Columbia (BC), Canada. Radiocarbon dates ranged from 182 to 9558 cal. yr BP, with prominent peaks in the probability distribution of calibrated dates at *c.* 7100, 3900, 2300, 1600 and 250–1000 cal. yr BP. The inferred median fire return interval (FRI) was 800–1200 cal. yr, depending on the extent of inbuilt age errors resulting from charring of wood pre-dating actual fire ages. This FRI is likely an overestimate, as less severe events may not have created sufficient erosion and slope instability to preserve a record of charcoal in buried soils and slope deposits. Median time since fire was 467 cal. yr based on ages of the uppermost charcoal found at each site, but the severity of heartrots in the dominant redcedars (*Thuja plicata* Donn ex D. Don) prevented independent confirmation of stand ages by dendrochronology. Sites with multiple charcoal-containing layers having similar radiocarbon ages can be explained with reference to contemporary post-fire mass-wasting processes. Peaks in fire-related sedimentation probability coincided broadly with periods of higher fire frequency *c.* 600–1000, 1300–2400 and 3500–4500 cal. yr BP inferred from sedimentary charcoal records at subalpine sites in southwestern BC. Correspondence with fire records from more distant sites in northwestern North America was less clear."

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"Douglas-fir is the principal seral tree species of the Cariboo Forest Region ICH Zone and typically dominates young and mature stands following wildfire. In the drier, plateau portions of the ICH Zone (ICHmk and ICHdk), where wildfires were moderately common, Douglas-fir stands, with an understory of redcedar, subalpine fir, and some western hemlock, cover much of the ICH landscape. In the wetter mountainous portion of the ICH (ICHwk), where wildfires were uncommon, few Douglas-fir stands are present. Even here, however, long-lived Douglas-fir trees are often present as remnants of an earlier seral stand."

"Vegetation of the ICHdk is transitional between the SBSdw1 and the ICHmk3 and distinguished from other ICH subzones by relatively dry climate shrubs such as saskatoon and soopolallie and the prevalence of lodgepole pine forests. Climax tree species on zonal sites are western redcedar and subalpine fir, but, due to frequent wildfires, climax forests are uncommon. Douglas-fir and lodgepole pine forests cover most of the landscape."

"The natural landscape of the ICHmk3 is blanketed by young, mature, and old forests of western redcedar, Douglas-fir, and lodgepole pine. Hybrid white spruce forests are common on moist valley bottom sites. Trembling aspen and paper birch forests occupy many recently burned sites. Due to past wildfires, young coniferous forests cover much of the landscape. On most sites, the young forests are dominated by Douglas-fir and/or lodgepole pine, with a dense understory of western redcedar and subalpine fir. The proportion of redcedar, subalpine fir, and spruce in the canopy generally increases as the stand ages, and old stands are typically dominated by western redcedar with scattered subalpine fir and spruce and an occasional Douglas-fir veteran. Western hemlock occurs infrequently in the understory."

"Stand-destroying wildfires have been relatively infrequent in the ICHwk. As a result, late seral and old forests cover most of the landscape. These forests are dominated by western hemlock and western redcedar and typically have minor components of subalpine fir and hybrid white spruce. Scattered old Douglas-fir trees are often present as veterans of an earlier seral stage. The understory has abundant redcedar, hemlock, and subalpine fir regeneration. Early and mid-seral forests are dominated primarily by Douglas-fir."

Wong, C., B. Dorner, and H. Sandmann. 2003. Estimating historical variability of natural disturbances in British Columbia. B.C. Min. For., Res. Br. and B.C. Min. Sustain. Resource. Manage., Resource Plan. Br., Victoria, B.C. Land Manage. Handb. 53.

www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh53.htm

"In our analysis of the Arrow Forest District, reported in Part 3, we found a much wider range in pre-settlement disturbance return intervals. Depending on assumptions about pre-harvesting age of stands and predominant disturbance characteristics, we estimated return intervals of 65–449 years for the ICHdw and 97–458 years for the ICHmw2."

INTERIOR DOUGLAS-FIR AND PONDEROSA PINE BIOGEOCLIMATIC ZONES

Alfaro, R., E. Campbell, and B. Hawkes. 2010. Historical frequency, intensity and extent of mountain pine beetle disturbance in British Columbia. Can. For. Serv., Pac. For. Cent., Victoria, B.C. Mountain Pine Beetle Work. Pap. 2009-30.

http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/31405.pdf

"The history of mountain pine beetle outbreaks was reconstructed from increment cores and basal disks collected from 85 stands across British Columbia and Alberta. Using aerial survey data, dendrochronological software was calibrated to detect growth releases that could be attributed to beetle outbreaks. In addition to the outbreak in the 1970s and 1980s, growth release data indicate that beetle outbreaks probably also occurred in the late 1870s and 1900s, and in the 1930s and 1940s. Growth release periods associated with beetle outbreaks lasted up to 20 years, with the magnitude of growth increases averaging 58% to 65%. Based on time intervals between growth release periods, we estimated a return-interval of beetle outbreaks of 30 to 40 years. Although the intensity of past beetle outbreaks appears to be greater in central British Columbia than further north or in Alberta, further investigations are required. A histogram of growth release frequencies among stands suggests outbreaks have become more extensive over the last century."

"Relationships between the occurrence of beetle outbreaks and fire history were undertaken using several approaches in dendrochronology. Dating of fire scars in the Cariboo–Chilcotin Plateau of central British Columbia indicated that fires were much less frequent in the 20th century than they were in the 19th century. This may explain the more extensive outbreaks of the 1930s and 1940s and 1970s and 1980s in this region. Stands in regions characterized by low- or mixed-severity fire regimes had more frequent outbreaks than those in regions where fires are stand-replacing disturbance events. Among stands that originated from stand-replacing fires, we found that the time since fire had an important influence on frequency of beetle outbreaks—outbreaks were most frequent in stands 50 to 100 years after fire, when mature trees are less resistant to beetle attack and thick phloem tissues promote beetle development."

Arsenault, A. and W. Klenner. 2005. Fire regime in dry-belt forests of British Columbia: perspectives on historic disturbances and implications for management. In: Mixed severity fire regimes: ecology and management. Proc. Conf. Nov. 17–19, 2004, Spokane, Wash. L. Taylor, S.C. Selnik, and B. Hughes (editors). Washington State Univ., Coop Exten. Serv., Pullman, Wash., pp. 105–121.
http://trench-er.com/public/library/files/arsenault-klenner.pdf

"We critically examine the hypothesis that dry-belt forests in BC were historically in a low-severity fire-maintained disturbance regime, and discuss some of the implications of our results to the management of these forests. We examined three sources of information that we believe lend some insight into past disturbance regimes and the stand structure conditions that likely prevailed: (1) systematic surveys prior to extensive management, (2) a fire scar analysis case study at Opax Mountain, (3) fire records.

Our analyses consistently indicate that natural disturbances were likely complex and non-equilibrium, creating changing patterns in both stand structure and landscape condition spatially and temporally. Several interacting factors including climate, forest harvesting, livestock grazing, fire suppression and changing geographic patterns of insect pest attack are key drivers in creating and maintaining the conditions observed today.

The wide range of conditions that have occurred in the last 10,000 years, and the uncertainty associated with predicting future conditions limits the utility of the concept of natural or historic variability. No one point in time should be chosen as the 'ecologically correct' reference period, and past non-equilibrium disturbances illustrate conditions that are not compatible with current social expectations. Future landscape planning and stand management should avoid the use of idyllic and misleading terms like 'ecosystem restoration' and focus on clearly defining desired stand conditions, the commodity objectives that will be met with these conditions, and the most effective (economical, social and ecological) tools for achieving the objective."

Axelson, J.N., R.I. Alfaro, and B.C. Hawkes. 2010. Changes in stand structure in uneven-aged lodgepole pine stands impacted by mountain pine beetle epidemics and fires in central British Columbia. For. Chron. 86(1):87–99. http://pubs.cif-ifc.org/doi/abs/10.5558/tfc86087-1

"We examined the development of lodgepole pine (*Pinus contorta* Dougl.) in uneven-aged stands in the Interior Douglas-fir (IDF) biogeoclimatic zone of central of British Columbia (B.C.), which are currently undergoing a massive outbreak of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins; MPB). Using historical ecological approaches, dendrochronology, and stand measurement data, we determined the roles MPB and fire disturbances have played in the ecological processes of lodgepole pine in an Interior Douglas-fir zone. We found that multiple mixed-severity fires created patchy uneven-aged stands dominated by lodgepole pine. Since fire suppression in the 20th century, multiple MPB disturbances have maintained the structural complexity of the stands and favoured regeneration of lodgepole pine in the understory despite the absence of fire, resulting in self-perpetuating multi-age lodgepole pine stands. Analysis of the stand structures remaining after multiple MPB outbreaks showed that, even with high overstory mortality, the sample stands contained several MPB-initiated cohorts, consisting of younger and smaller-diameter lodgepole pine. These surviving lodgepole pine layers, which are less susceptible to beetle, will provide important ecological legacies, and could play an important role in the mid-term timber supply chain. We concluded that, in the absence of fire, the MPB plays a more frequent role in directing stand dynamics and structure in uneven-aged lodgepole pine stands resulting in self-perpetuating complex stands in the central interior. We compared and contrasted these findings with those obtained in 'even-aged' lodgepole pine stands, also in the Interior Douglas-fir zone in the southern interior, which were investigated in an earlier study."

Blackwell, B.A., F. Steele, R.W. Gray, K. Iverson, and K. MacKenzie. 2001. Fire management plan—Churn Creek Protected Area. Prepared for BC Parks, Cariboo Distr., Williams Lake, B.C. Unpubl. rep.

For one site in the IDFxm in the Churn Creek Protected Area, the Mean Fire Interval was 14 years. (cited by Wong et al. 2003 www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh53.htm)

Braumandl, T.F. and M.P. Curran (compilers and editors). 2002. A field guide for site identification and interpretation for the Nelson Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 20. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh20.htm

The PPdh1 occurs in "the southern extremities of the Kettle River Valley. Valley bottoms and mid to lower elevations on south-facing slopes and terraces between Johnstone Creek and Boundary Falls and between July Creek and Christina Lake." "The PPdh1 is dominated by grassland and open Py [ponderosa pine] stands. Frequent low intensity ground fires are the major disturbance feature."

The PPdh2 is found in the "Rocky Mountain Trench between Skookumchuck Creek and the St. Mary River and between Baynes Lake and Tobacco Plains." "This variant is dominated by drier sites and has had an extensive fire history. It has a legacy of intensive domestic grazing and selective logging. Coupled with a more recent trend toward fire management and controlled grazing, the area has become a complex mosaic of vegetation communities in response to the fluctuating disturbance and use." "Forest ingrowth is a problem because of fire suppression."

The IDFdm1 is found "in the southern extremities of the Monashee Mountains, along valley bottoms and lower slopes. Predominantly in the Kettle and Granby river drainages." "Frequent wildfires and extensive selective logging have left very few old-growth stands." "Forest ingrowth reduces forage production at lower elevations." "Fire's major role has resulted in stands with large, old Douglas-fir and ponderosa pine."

The IDFdm2 occurs along "valley bottoms and lower slopes of the Rocky Mountain Trench south of the Blaeberry River, and valley bottoms of major tributary valleys such as the Spillimacheen, Kootenay, Finlay, St. Mary, and Wigwam." "Frequent wildfires and extensive selective logging have left very few old-growth stands. After wildfire, Pl [lodgepole pine] is common in seral stands. Mature stands consist of an open canopy of Fd [Douglas-fir] with pinegrass in the understory." "Forest ingrowth reduces forage production at lower elevations." "Fire's major role has resulted in stands with large, old Douglas-fir and ponderosa pine."

Brayshaw, T.C. 1955. An ecological classification of the ponderosa pine stands in the southwestern Interior of British Columbia. PhD thesis. Univ. British Columbia, Dep. Biol. Bot., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/40361

In the Nicola Valley, "a recently cut stump was found which revealed a series of fire scars, which recorded grass fires which had scorched this stump. Fires had occurred since 1750 at intervals varying from three to 41 years. The last fire thus recorded was in 1879. Since sagebrush is less inflammable than grass, this date may indicate the approximate time of the original changeover from grass to sagebrush, resulting from the grazing of livestock brought in by white settlers some 20 years or so before."

Campbell, R., D.J. Smith, and A. Arsenault. 2006. Multicentury history of western spruce budworm outbreaks in interior Douglas-fir forests near Kamloops, British Columbia. Can. J. For. Res. 36(7):1758–1769.
www.nrcresearchpress.com/doi/abs/10.1139/x06-069

"Western spruce budworm (*Choristoneura occidentalis* Freeman) is a native defoliator of forests in the interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) forests of British Columbia, Canada. Dendrochronological techniques and the software program OUTBREAK were used to reconstruct a defoliation history of Douglas-fir for 19 forest sites near Kamloops in central British Columbia. By comparing the radial-growth response of ponderosa pine (*Pinus ponderosa* Dougl. ex P. Laws. & C. Laws.) with that of Douglas-fir growing in nearby but separate stands, eight western spruce budworm outbreaks over the past 300 years were distinguished. Although there is considerable variation in the timing and duration of these western spruce budworm events at the stand level, synchronous outbreaks have occurred in approximately 30- to 43-year cycles. Spectral analyses of a composite time series from all stands showed similar and consistent intervals between outbreaks. Climatic variation appears to have been important to budworm outbreaks in the 20th century. Notable outbreaks tended to occur during years with average spring air temperatures following winters with less than average precipitation. Based on this finding, it is proposed that with high over-winter survival rates and a longer growing season, the duration of outbreaks may increase in the future."

Cartwright, D. 1983. Evaluating the effects of prescribed burning on bighorn sheep. BSF thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.

Fire scar data from Battle Bluff, near Kamloops, indicate a surface fire frequency of 9.7 years between 1757 and 1913 for a mixed ponderosa pine–Douglas-fir forest.

Daigle, P. 1996. Fire in the dry interior forests of British Columbia. B.C. Min. For., Res. Br., Victoria, B.C. Exten. Note 08. www.for.gov.bc.ca/hfd/pubs/Docs/En/En08.pdf

"Before European settlement, dry low elevation interior forests and grasslands experienced frequent, low-intensity wildfires or purposeful fires set by aboriginal peoples every 5–20 years."

"During this [20th] century, fire prevention, urbanization, domestic grazing, forest harvesting, and road networks have changed dry interior forests substantially. Fire suppression activities have increased the average fire interval dramatically." "The historical fire frequency varied between 7 and 20 years. In more recent times, most of these sites have not had fires for 30 to nearly 90 years."

Daniels, L.D. 2005. Climate and fire: a case study of the Cariboo forest, British Columbia. In: Mixed severity fire regimes: ecology and management. Proc. Conf. Nov. 17–19, 2004, Spokane, Wash. L. Taylor, S.C. Selnik, and B. Hughes (editors). Washington State Univ., Coop Exten. Serv., Pullman, Wash., pp. 235–246. http://trench-er.com/public/library/files/climate-fire-cariboo.pdf

"Historically, fire was a primary agent of disturbance in Douglas-fir–lodgepole pine forests of central British Columbia, Canada. The historic fire regime included low-severity, stand-maintaining fires and less frequent, stand-replacing fires. At the stand level, fire intervals ranged from two to 59 years, with median intervals of 13 to 22 years. Fire intervals doubled when considering only fires that scarred at least two recorder trees per plot, indicating that severe fires burned less frequently than low-severity fires. Current fire free intervals exceed historic median intervals at all plots and maximum intervals at six of nine plots. Links between climate variation and fire in the Cariboo forests between 1700 and 1970 were consistent with climate–fire relationships in dry forests in the southwest US, but opposite to patterns in the

Pacific Northwest. In the Cariboo, fires burned during droughts that correspond with La Niña conditions. Understanding the links between climate variation and fire allows managers to use climate forecasting to anticipate annual to decadal periods of increased fire risk.

Restoring and managing the Cariboo forests is challenging due to the complexity of the mixed-severity fire regime. In many stands, mitigation of fuels accumulated during the fire suppression era will be a form of ecological restoration. However, some accumulations are to stand development following high-severity fires in the past century and restoration is not needed. In spite of effective mitigation, fires will burn under appropriate climate conditions. Scientists and managers need to work with communication experts to ensure the public understands that restoration and mitigation will not eliminate fire from our forests. Rather, restoration and mitigation are management tools to be applied strategically at stand and landscape levels to reduce risk of fire in specific culturally, socially, or economically valuable forests."

Daniels, L.D., J. Dobry, and K. Klinka. 1995. Fire history of two Douglas-fir stands in the Alex Fraser Research Forest: a pilot study—1994/95. Report to Cariboo Forest Region, B.C. Min. For. and Univ. British Columbia, For. Sci. Dep., Vancouver, B.C.

"This pilot study explores the application of dendrochronological methods to document the fire history of Douglas-fir stands in the Interior Douglas-fir biogeoclimatic zone [IDFdk] of British Columbia. Increment cores were extracted from 42 trees on one site and cross-sectional discs taken from nine fire scarred trees on two sites in the Alex Fraser Research Forest near Williams Lake. The cores were used to develop robust standard and residual chronologies which were used to analyze climate–growth relationships and crossdate the fire-scarred discs.

Between 1754 and 1915, 12 and 5 fires burned on sites 1 and 2, respectively. Fires of moderate to high severity burned on both sites in 1837 and 1858. During the 18th and 19th centuries, fires were more frequent on site 1 (mean fire interval [MFI] = 16.64 years) than on site 2 (MFI = 18.00 years). Fire frequency has declined since European settlement and has been eliminated from sites 1 and 2 since 1915 and 1893, respectively.

There was abundant evidence of the influence of insects in the study area. Long-term trends in the standard chronology suggested that they have affected tree growth during past infestations. Analysis of tree growth relative to climate showed significant relationships, suggesting a high potential for future climate reconstruction and investigation of fire–climate–insect interactions."

Daniels, L.D., Z. Gedalof, M.F.J. Pisaric, C.J.C. Mustaphi, E. Da Silva, H. Marcoux, V. Mather, J. Nesbitt, E. Paul-Limoges, J. Perrault, and C. Steele. 2011. Historic climate-fire-vegetation interactions of the West *versus* East Kootenays: implications of climate change and fire suppression. Prepared for Univ. British Columbia, Dep. Geog., Vancouver, B.C.; Carleton Univ., Dep. Geog., Ottawa, Ont.; and Univ. Guelph, Dep. Geog., Guelph, Ont. http://trench-er.com/public/library/files/kootenay-fire-report.pdf

"In western North America, wildfire is a primary disturbance driving the diversity, age structure, and dynamics of forest. In some forests, climatic warming combined with fire exclusion has created conditions conducive to catastrophic wildfires. Understanding the relationships between wildfire and environmental change is a fundamental concern, particularly in forests near the wildland-urban interface where human lives and property are at risk. In this project, we compared the fire history and forest dynamics of the Joseph-Gold Creek watersheds near Cranbrook in the East Kootenay district and remnant old forests surrounding Nelson in the West Kootenay district of southeastern British Columbia.

We used multiple lines of evidence, including charcoal in lake sediments and analysis of tree rings, to reconstruct historic fire regimes. In both the West and East Kootenay study areas, fire regimes varied significantly with steep elevational gradients. At high elevations, stand-replacing fires burned every 150-300 years according to our lake sediment, fire scar and forest age results. The lake sediment research yielded a 10,000-year fire reconstruction for high elevations (>2000 m.a.s.l.) in the West Kootenay study area. It included 36 fires, burning once every 270 years on average. Fire frequencies peaked 4,000-6,000 years ago, but 2-3 large fires burned during the past 1,000 years. There was at least one large fire in the early 1900s. Forest history reconstructions from tree rings corroborated this evidence. In the West Kootenay study area, high elevations forests established after severe fires that burned up to 340 years ago but many forests established from 1850 to the 1890s, concurrent with the gold rush and European settlement. In the East Kootenay study area, severe fires burned 100-360 years ago. A widespread fire in 1910 affected the forests at all elevations, scarring many trees, and killing even fire-resistant tree species.

In the low-elevation forests, below 1350 m.a.s.l. in the West and 1550 m.a.s.l. in the East Kootenays, there was abundant evidence of frequent, low-severity fires that burned and scarred trees once every 25 to 50 years, on average. Fires burned in late summer of drought years, often during the warm phase of the Pacific Decadal Oscillation, a climate cycle causing warm, dry conditions in the Kootenay region. Despite the historic frequency of fires and recent periods of suitable climate, these forests last burned 56 to 159 years ago. The unusually long fire-free periods are evidence of the strong effects of fire exclusion and suppression during the 20th century. The lack of recent fires was reflected in the composition of low-elevation forests in both study areas. The forest canopies were dominated by thick-barked, fire-tolerant species but subcanopy trees were shade-tolerant, thin-barked species that are susceptible to fire. Although small, the subcanopy trees were the same age as the canopy trees; they established after the last fire and did not represent continuous in-filling of the forest. Historically, the low-severity fires would have killed the smaller thin-barked trees and consumed fine fuels such as needles and branches on the ground. In absence of low-severity fires, dense forests have been perpetuated and ground fuels have accumulated. Paradoxically, by protecting the forests from low-severity fires, we have likely increased the risk of severe wildfires in the low-elevation forests surrounding Cranbrook and Nelson."

Daniels, L.D. and E. Watson. 2003. Climate-fire-vegetation interactions in the Cariboo forests: a dendrochronological analysis. For. Innovation and Investment For. Res. Program.
http://trench-er.com/public/library/files/climate-fire-vegetation-interactions.pdf

"Dendrochronological techniques yield high-quality data for reconstructing historical change in forests and quantifying temporal aspects of disturbance regimes. In this study, we used annual-resolution tree-ring data to investigate: (1) the influences of year-to-year climate variation on tree growth and fire occurrence, and (2) the impacts of fire on forest structure and dynamics in the Cariboo region of British Columbia.

We developed 14 new ring-width chronologies, six for Douglas-fir and eight for lodgepole pine. The chronologies were used to crossdate age and fire scar samples and to test for climate-tree growth relationships. Chronologies for both species were positively correlated with Williams Lake precipitation, indicating that wet (dry) summers result in wide (narrow) annual rings. The Douglas-fir chronologies were selected for climatic reconstruction since they were longer, exhibited more inter-annual variation, and had a stronger common signal between trees than the lodgepole pine chronologies. The Douglas-fir ring-width chronology from site 6 was combined with a ponderosa pine late-wood chronology from Chasm (provided by E. Watson) in a statistical model that we used to reconstruct precipitation in our study area from c. 1630 to 1995.

Crossdating of 136 samples yielded 280 fire-scar dates ranging from 1575 to 1988. At the plot spatial scale, fire intervals ranged from two to 59 years, with median intervals of 13 to 22 years. Fire intervals doubled when we considered only fires that scarred at least two recorder trees per plot, indicating that severe fires burned less frequently than low-severity fires.

Fire was a primary determinant of stand structure and dynamics in the Douglas-fir – lodgepole pine forests of the Cariboo region. The mixed fire regime includes both low-severity stand-maintaining fires and less frequent stand-replacing fires. Evidence of stand-maintaining fires included uneven age-structures, low density of veteran trees, Douglas-fir with up to eight fire scars, and lodgepole pine with multiple fire scars. Discrete cohorts of trees with fast initial growth rates indicated stand-replacing fires. In eight of the nine study plots, cohorts of trees established following fires that burned in the late 1800s or early 1900s. Post-fire stand development processes such as crown closure, inter-tree competition and self-thinning were evident in the radial growth suppressions and releases of individual trees.

For forests with mixed fire regimes that include stand maintaining and stand-replacing fires, it is difficult to quantify the impacts of fire suppression and to determine whether current stands differ from historic stands. Nevertheless, the current fire-free interval exceeded the median fire return interval at all plots and the maximum interval at all but two plots. Weak correlations suggested that long fire intervals may explain the density of canopy and subcanopy trees observed in some plots, but additional data are needed to draw meaningful conclusions. The radial growth rates of contemporary saplings are much lower that the initial growth rates of subcanopy and canopy trees. Slow sapling growth may be due to competition from overstory trees and low light availability, implying that current stand structures are different from historical conditions.

We used our fire scar records, precipitation reconstruction, and El Niño-Southern Oscillation (ENSO) indices to test for climatic influences on fire occurrence between 1700 and 1970. Links between El Niño-Southern Oscillation, interannual variation in climate, and fire in the Cariboo region were consistent with climate-fire relationships in other dry forests in North and South America. Fire occurrence was related to droughts that last three to five years and correspond with the onset of strong La Niña events. Fires commonly burned in the second year of a drought, following desiccation of fine and coarse fuels. Years of above average precipitation preceded fire years and likely contributed to build up of understory vegetation and fine fuels. Future research will test for climate-driven changes in the fire regime over periods of decades to centuries and attempt to differentiate between the influences of climate and human impacts on the Cariboo fire regime.

The links between climate and fire are regionally important given the current mountain pine beetle outbreak in British Columbia. This research suggests that risk of catastrophic fire in the Cariboo forests will be greatest if a strong La Niña event coincides with peak fuel accumulations resulting from the current outbreak. In 2002, we experienced a moderate El Niño event - La Niña events typically follow El Niños by three to five years."

Da Silva, E. 2009. Wildfire history and its relationship with top-down and bottom-up controls in the Joseph and Gold Creek watersheds, Kootenay Mountains, British Columbia. MSc thesis. Univ. Guelph, Guelph, Ont. http://trench-er.com/public/library/files/wildfire-history-joseph-gold-creeks.pdf

"This study identifies patterns of historic fire activity that characterise the Joseph and Gold Creek watersheds near Cranbrook, British Columbia as a mixed-severity regime and provide evidence that both bottom-up and top-down controls significantly regulate fire activity. Fire scar chronologies from 33 plots in the watersheds demonstrate that the relative importance of bottom-up controls vary over very short distances. Fire frequency was significantly higher in plots found on a steep southwest-facing sloping compared with the rest of the landscape, an area characterised by xeric conditions. Species distribution was strongly driven by elevation related microclimate and transitioned from fire-resistant to sub-alpine species along elevation gradients, likely reflecting a transition in fire activity – although this could not be substantiated by the fire scar record because of a lack of fire history information. Historic fire activity in this area showed a strong relationship with drought, which may be associated with the warm phase of the Pacific Decadal Oscillation. Similar results were found when analyses were completed using regionally significant fire years. The effects of fire exclusion in the past half century are evident in this fire history reconstruction. The low incidence of fire in the hundred years following a large event in the early 20th century has served to homogenize the landscape and increase fire hazard in the wildland-urban interface."

Dawson, R. 1998. Landscape attributes of interior Douglas-fir forests on the Fraser Plateau. In: Managing the dry Douglas-fir forests of the Southern Interior: workshop proceedings. Apr. 29–30, 1997, Kamloops, British Columbia, Canada. A. Vyse, C. Hollstedt, and D. Huggard (editors). B.C. Min. For., Res. Br., Victoria, B.C. Work. Pap. 34, pp. 9–20. www.for.gov.bc.ca/hfd/pubs/docs/wp/wp34.htm

"In the last 40 years especially, fires have been vigorously controlled in the IDFdk3. Fire suppression has affected the two main forest types of the IDFdk3 differently. In the lodgepole pine type, suppressing fires has probably resulted in fewer natural young stands, while a greater area of mature and old forests has developed because past wildfires were primarily stand-replacing. In the Douglas-fir type, however, fire suppression has probably not increased the area in young stands, but has altered the structure of mature and old stands. The major change is increased density of Douglas-fir in intermediate and suppressed canopy layers. Data from the Alex Fraser Research Forest in the IDF just outside the study area indicate that fire has been absent for the past 80 years in stands that previously experienced wildfire on average every 12 years.

Results showing a natural reference landscape dominated by a matrix of older forest types in large, well-connected patches are consistent with a disturbance regime of relatively infrequent stand-destroying disturbances. This pattern is especially apparent at lower elevations in the study area where older Douglas-fir stands occupy over 80% of the forested area. Where stand-destroying fires are infrequent, many stands survive to old age, which results in a landscape dominated by a matrix of mature and old forests. The results are also consistent with a regime of frequent low-intensity ground fire that favours the development of biological communities made up of fire-resistant species such as Douglas-fir. The lodgepole pine component of the landscape, which is increasingly concentrated in the higher elevations in the study area, shows a greater spread in age-class distribution. This type of age-class distribution is more characteristic of the regime of frequent stand-destroying fires common in the adjacent Sub-boreal Pine–Spruce Biogeoclimatic Zone."

Dorey, R.J. 1979. A fire history investigation and the effects of fire exclusion on a ponderosa pine forest in southeastern British Columbia. BSF thesis. Univ. British Columbia, Fac. For., Vancouver, B.C. http://trench-er.com/public/library/files/fire_history_tobbaco_plains.pdf

"This paper describes frequencies of fire in a ponderosa pine (*Pinus ponderosa* Dougl.) stand in the East Kootenay region of British Columbia. A study area was established and 14 fire wounds were sampled. The 56 individual fire scars revealed an average fire periodicity of 6.4 years with a range of from 2 to 13 years from 1813 to 1940. The 38 years since 1940 represents the longest fire-free interval recorded in the study area [Tobacco Plains]." Fire frequency was 5.9 years prior to, and 9.6 years after, 1911.

Douglas, K.L. 2001. Historical analysis of fire intervals of two biogeoclimatic units in the central Chilcotin, British Columbia. BSc thesis. Univ. Northern British Columbia, Prince George, B.C.

"Historical variability in lodgepole pine fire intervals is a necessary consideration for management that aims at maintaining natural biodiversity across forested landscapes. This fire history study examined fire-scarred lodgepole pine cross-sections collected from the dry cool Interior Douglas-fir (IDFdk) and the very cold Sub-Boreal Pine – Spruce (SBPSxc), two biogeoclimatic units of British Columbia. Fire years were determined by counting growth rings and then adjusting fire dates based on synchronization with fire dates of adjacent trees. The IDFdk unit had a Weibull Median Interval (WMI) of 12.88 years, with minimum and maximum fire intervals of 5 and 44 years, respectively. The SBPSxc unit had a WMI of 9.29 years, with minimum and maximum fire intervals of 1 and 50 years, respectively. The relatively short fire intervals suggest that fires were likely of low to moderate intensity between the 1830s and mid-1900s. The presence of more than one fire scar on individual cross-sections also suggests that fire intensity was not extreme. When fire intervals of the biogeoclimatic units were compared against each other, it was found that no significant difference exists between the fire intervals."

Enache, M.D. 2006. Mid to late Holocene fire and climate dynamics inferred from lake sediments from Interior British Columbia, Canada. PhD thesis. Queen's Univ., Dep. Biol., Kingston, Ont.

"A number of distinct charcoal morphotypes were defined in this study and used along with diatom assemblages from lake sediments to investigate the relationships between fire and climate at decadal through millennial scales from the Interior British Columbia. Charcoal fragments were classified into seven distinct morphotypes according to their morphological and structural characteristics using optical microscopy. The contemporaneous relationship between charcoal morphotypes and recorded area burned was assessed from three lakes in different biogeoclimatic zones [ESSF, IDF, SBS] between 1919-2000. The distribution of each charcoal morphotype showed distinct differences over time. In Prosser Lake [IDF-ESSF boundary] type-M charcoal was significantly correlated to area burned around Prosser Lake at radii up to 20 km, whereas type-C morphotype was correlated to area burned at a radius <10 km, and type S at a 20-km radius. In Opatcho Lake, morphotype M was the only charcoal type significantly correlated with area burned. Charcoal from Big Lake [IDF] was inversely related to past area burned, suggesting important contribution from secondary deposition. The strong correlation between type-M charcoal and area burned was used to develop an index of area burned. The charcoal-morphotype approach at inferring past fires was further assessed by longer-term reconstructions of climate at a subdecadal resolution over the past 400 years and centennial-scale resolution over the last six millennia in sediment cores from Opatcho Lake. Climate proxies were developed using variations in diatom assemblages and supported with regional proxies of temperature and precipitation. In both cases, the reconstructions indicates that synoptic-scale climate variations were significantly related to morphotype-based reconstruction of fire, but were not related to total charcoal. This new technique suggests that fires were ~5 times more common than present day between 4500-6000 yrs B.P., a well known period of aridity. Models suggest that B.C. will get increasingly arid. A similar fire regime to that observed in the mid Holocene should be expected."

Feller, M.C. and K. Klinka. 1998. Fire history and ecology of B.C. interior Douglas-fir forests, final report – May 1998. For. Renewal BC, Res. Program. Univ. British Columbia, Fac. For., Vancouver, B.C. www.for.gov.bc.ca/hfd/library/frbc1998/frbc1998mr141.pdf

"A study was conducted in the IDFdk3 biogeoclimatic variant in the Cariboo Forest Region, with the objectives of determining fire frequencies in forests and the influence of these frequencies on existing stand structure. A total of 14 plots (stands) between Williams Lake and Clinton were assessed. Ring width standard chronologies were developed for the 14 plots, then used to date fire scars on trees. Mean fire return intervals decreased from 70+ years in the 1600's to 27 years in the 1800's, then increased to 54 years this century. From approximately 1700 to 1995, eleven regional fire episode periods were found. These coincided closely with such periods found elsewhere in the Cariboo and in the U.S. Inland Northwest.

The 14 stands varied widely in structure (species composition and tree diameter and age distributions) and had experienced from 1 to 21 scar-producing fires. However, assessment of the influence of fire frequency or history on stand structure has not yet been very conclusive. There was some indication that the incidence of 2 relatively severe fires within a short time period could help explain the distribution of lodgepole pine, but other aspects of stand structure were not easily explained.

Douglas-fir and lodgepole pine radial growth were positively correlated with monthly precipitation in the previous summer, and negatively to temperature in the previous summer using weather data from a weather station at Williams Lake. Relationships between ring width from the standard chronologies and precipitation and temperature are being used to reconstruct past weather and to assess weather during fire episode periods, but this has not yet been accomplished."

Gray, R.W., B. Andrew, B.A. Blackwell, A. Needoba, and F. Steele. 2002. The effect of physiography and topography on fire regimes and forest communities. Prepared for Habitat Conservation Trust Fund, Victoria, B.C. www.for.gov.bc.ca/hfd/library/FIA/2002/FIA2002MR009.pdf

"The historic fire regimes found in south aspect NDT3 and NDT4 polygons sampled in 5 forest districts (Invermere [IDFdm2, MSdm1], Cranbrook [IDFdm2, MSdk], Kamloops [IDFdk1, IDFxh2, MSxk1], Lillooet [PPxh2, IDFdk1], and Squamish [IDFww, ESSFmw]) were characterized by high fire frequency with narrow variability around the mean, and variable intensity. Mean fire intervals (MFI) recorded for the 5 sites ranges from a low of 6.5 for Lillooet and a high of 17.9 for Invermere. The MFI's recorded are some of the lowest numbers recorded in the province.

The results of the analysis on south aspects suggest frequent, mixed-severity fire regimes have influenced historic stand structure and ecosystem processes in biogeoclimatic subzones and variants currently considered to have experienced infrequent stand-replacement fire regimes. This is true for the MSdk in Cranbrook, MSdm1 in Invermere, MSxk in Kamloops and Lillooet, and the ESSFmw in Squamish. Additionally, significant issues exist in some Forest Districts concerning inaccuracies in the current mapped distributions of biogeoclimatic units. These identified discrepancies can have significant consequences where the conservation of biodiversity is concerned. The current designation of many of these biogeoclimatic units as Natural Disturbance Type 3 warrants further investigation. Fires appear to be of more mixed-severity as opposed to infrequent, high-severity."

Gray, R.W. and L.D. Daniels. 2007. An investigation of fire history in the lower Gold/Joseph Creek watershed. Prepared for City of Cranbrook, Cranbrook, B.C.
www.trench-er.com/public/library/files/joseph-creek-fire-history.pdf

"The interval for fire analysis was from 1302, the year of the inner ring of the oldest ponderosa pine, through 2006. We crossdated 46 fire scars, with one to nine fire scars per tree. We identified 27 fire years between 1323 and 1936. Fire years in which multiple trees scarred were 1522, 1688, 1721, 1739, 1831, 1869, 1898, and 1910; in 1721, 1831, 1869 and 1910 fires also burned at the Joseph Creek West site [MS]. The Weibull median interval between fires was 20 years. The minimum interval between successive fire scars was three years, between 1599 and 1602, 1828 and 1831, and 1866 and 1869. The maximum interval between fires was the 69 years from 1430 to 1499, more than 500 years ago. It is possible once again that fires burned during that time but fire scar evidence may have been burned off or the scarred trees may have decayed. The last fire scar was formed in 1936, so that it had been 71 years since the last fire when we sampled the study site in 2006."

"Historic fire frequency of the Joseph Creek East site [IDFdm2] was not significantly different from that of the Joseph Creek West site, but the fire record at Joseph Creek East was longer, spanning 613 years from 1323 to 1936. The oldest samples collected for fire history analysis were from charred, partially consumed ponderosa pine snags. These trees lived at least 200 to 480 years and survived numerous fires, and eventually died in the late 1700's and early 1800's. More recently, several fire scarred Douglas-fir and western larch established during the 1700's, many of which were alive at the time of sampling."

Gray, R.W., J. Nesbitt, and L. Daniels. 2009. An investigation of fire history and forest dynamics and their impact on wildfire hazard in McLeary Park, Cranbrook. Prepared for City of Cranbrook, Cranbrook, B.C.
www.trench-er.com/public/library/files/mcleary-park-fire-history.pdf

"…we analyzed the period between 1533 and 1938 for fire analysis…. These two dates correspond to the earliest inner ring date in the sample and the latest outer ring date. The 1938 outer ring date roughly corresponds to the latest timber harvest date in the park. Individual trees exhibited from one to 13 fire scars. The minimum interval between fires was three years and this pattern occurred three times: from 1626 to 1629, 1634 to 1637, and 1645 to 1648.

The maximum interval between fires was 18 years from 1881 to 1899; the 1899 fire was also the last fire recorded on the site. The Weibull Median Interval between fires was 7.7 years. This statistic is a conservative estimate of fire activity on the study site as very low intensity fires could have burned through the site and not scarred any trees, even those already scarred. Of 18 cross-dated samples with outer-ring dates following the 1899 fire, five exhibited external char meaning they had been exposed to a fire but didn't record the fire in the growth rings."

"At McLeary Park, records from fire-scarred trees indicate a history of low-severity fires dating back to the early 1500's. At the end of the fire history record, in the late 1930's, forest density was approximately 28 mature trees/ha, with most being western larch and ponderosa pine. In 2005, just prior to thinning operations to reduce fire hazard in the park, fire had not been recorded on the site for 116 years, stand density had increased to 3,500 to >10,000 trees/ha (including immature trees), and species composition had shifted from fire-tolerant western larch/ponderosa pine to less fire-tolerant Douglas-fir. The very frequent fire record from the early 1500's to the late 1800's, combined with the fire-scarred tree species found on the site, suggests that for three centuries the area known as McLeary Park was more of an open, treed savanna than a closed forest."

Gray, R. and E. Riccius. 1999. Historical fire regime for the Pothole Creek Interior Douglas-fir research site. B.C. Min. For., Res. Program, Victoria, B.C. Work. Pap. 38.

www.for.gov.bc.ca/hfd/pubs/docs/wp/wp38.htm

"Fire is an important historical disturbance factor in most stands of British Columbia interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*). Evidence of fire history was studied at the Pothole Creek Research Site (IDFdk1 biogeoclimatic subzone) near Merritt, B.C., as part of a larger project investigating stand development and growth and yield. A master chronology, constructed using samples taken from climatically sensitive trees, was used to cross-date samples collected from fire-scarred wood. The resulting pattern of past fire intervals was then employed to speculate about the historical fire regime at Pothole Creek. Evidence was found of fires occurring as long ago as 1693 and as recently as 1967. The mean fire interval was 13 years, within the expected range for interior Douglas-fir forests. The minimum and maximum intervals were 1 year and 46 years, respectively, indicating varying periods of both low-intensity/high-frequency fire and higher-intensity/low-frequency fire. This high disturbance frequency promotes plant species with adaptations to fire, such as Douglas-fir and pinegrass (*Calamagrostis rubescens*), and an open stand structure with sparse, patchy regeneration. The most severe fires identified on the site were not sufficiently intense to destroy the overstorey."

Gray, R.W. and E. Riccius. 2000. Ecosystem health and risk assessment in fire-maintained landscapes in the north end of the Squamish Forest District. R.W. Gray Consulting, Ltd., Chilliwack, B.C.

Four locations in the IDFww were examined. A site in the Birkenhead watershed experienced fires from 1744 to 1934, with a mean fire interval of 12.7 years. The minimum interval was 1 year (1897–1898), and the maximum was 53 (1840–1893). On Blackwater Creek there had been fires from 1771 to 1896, with a mean fire interval of 13.9 years. The minimum interval was 5 years (1868–1873), and the maximum was 25 years (1771–1796). At the Gates River site there had been fires from 1701 to 1940, with a mean fire interval of 15.9 years. The minimum interval was 4 years (1760–1764), and the maximum was 45 years (1895–1940). On Haylmore Creek an abundance of sample trees indicated that there had been fires from 1674 to 1906, with a mean fire interval of 6.4 years. The minimum interval was 2 years (1822–1824, 1827–1829, 1839–1841, 1860–1862, 1890–1892, 1892–1894), and the maximum was 24 years (1751–1775).

Gray, R.W., E. Riccius, and C. Wong. 1998. Comparison of current and historic stand structure in two IDFdm2 sites in the Rocky Mountain Trench. www.trench-er.com/public/library/files/lewis-isidore-fire-history.pdf

"The fire history from our samples for Lewis Ridge spans a period of 430 years with the earliest recorded fire occurring in 1586 and the most recent recorded fire occurring in 1883.... This corresponds to 14 years with fires recorded on samples from this site. Thirty-two fire scars occurred on the 9 samples with an average number of about 4 scars per sample." "Using the POR [period of reliability] from 1694 to 1883, we found a mean fire interval of 18.9 years. The minimum fire interval was 3 years [1694–1697] and the maximum was 52 years [1831–1883]. Of course, there has been a fire free interval of much longer, 115 years, from the last fire [1883] to the present [1998]."

"The fire history from the Isadore Canyon samples spans a period of 403 years with the earliest fire occurring in 1595 and the last fire occurring in 1894.... During this time period we identified 19 years with fire. A total of 38 fire scars occurred on the 7 samples which corresponds to an average of about 5 scars per sample." "For the POR from 1683 to 1894 the mean fire interval was 14.1 years. The minimum interval between fires was 1 year [1826–1827], while the maximum interval was 29 years [1751–1780]. A fire was not recorded on any of our samples in the last 104 years."

Gray, R.W., E. Riccius, and C. Wong. 2004. Comparison of current and historical stand structure in two Interior Douglas-fir sites in the Rocky Mountain Trench, British Columbia, Canada. In: Proc. 22nd Tall Timbers Fire Ecol. Conf.: Fire in temperate, boreal, and montane ecosystems. Oct. 15–18, 2001, Kananaskis, Alta. R.T. Engstrom and W.J. de Groot (editors). Tall Timbers Res. Stn., Tallahassee, Fla., pp. 23–35. www.trench-er.com/public/library/files/current_historical_stand_structure.pdf

"Contemporary stand characteristics in the dry Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) types of western North America are very different than in the era that pre-dates European settlement. Historic stand structure consisted of well-spaced, large-diameter trees, sparse pockets of younger trees, and a highly diverse understory. Naturally occurring fires, on the order of every 2 to 15 years, created bare mineral soil seedbeds and reduced grass competition sufficiently to permit the regeneration of individual trees and clumps. Contemporary stands consist of dense thickets of sapling and pole-sized trees, occasional large-diameter overstory trees, and poorly developed understory communities. The incidence of insect, disease, and catastrophic fire disturbance is increasing in these forest types. The changes in stand structure and disturbance regime are due to a combination of livestock grazing, favorable climate for seed production and germination, and fire suppression. Restoration and management of these ecosystems is now considered to be the most effective strategy for preserving biodiversity, maintaining endangered species, and avoiding catastrophic disruption of ecosystem functions. The first step in ecosystem restoration is establishment of historic reference conditions utilizing methods to determine the historic range of variability for ecosystem structure, composition, and the dominant disturbance regime. Historical fire regime data were collected and analyzed from two sites in the Rocky Mountain Trench of British Columbia. The fire regime from both sites are characterized as frequent, with mean fire intervals of 14.1 and 18.9 years. Historic and contemporary stand structure and composition were determined from a series of sample plots located in the two sites. Plot data showed variability in tree regeneration in the past, significant stand density increases since the late 1800s, and a shift in tree species composition. Many structure and composition changes appear to be aspect dependent. The study results indicate a significant departure in ecosystem structure, composition, and disturbance regime from the historical reference condition. While much of the study data cannot be overly extrapolated across the Rocky Mountain Trench, some initial guidelines for restoration efforts can be derived."

Hall, L.R.M. 2008. The fire history of a 416-year-old western larch tree in southeastern British Columbia. BC J. Ecosystems Manag. 9(2):5–10.
http://jem.forrex.org/index.php/jem/article/view/391

"The fire history obtained from pre-settlement fire-scarred trees provides useful benchmarks for the restoration of dry interior, fire-dependent forest ecosystems. In the Rocky Mountain Trench of southeast British Columbia, historical benchmarks obtained from periods prior to significant European influence (i.e., pre-1850) are common reference points for forest ecosystem restoration. This extension note discusses the fire history of a 416-year-old western larch (*Larix occidentalis*) whose growth rings recorded 268 years of fire history before 1850. The study tree's estimated mean fire interval (MFI) is 34.1 years, and its fire intervals ranged from 19 years to 51 years. The tree did not record a fire during the last 130 years of its life. This extension note also discusses the development of a network of cross-dated benchmark sites across the landscape that would create a master fire chronology for the region. Such a chronology would reflect the natural variability of historical fire patterns, helping policy-makers, managers, recovery teams, and restoration practitioners understand the spatial and temporal distribution of landscape-scale disturbances that historically have created fire-dependent ecological communities (many of which include wildlife and plant species now at risk). The creation of a benchmark network would also refine dry interior forest restoration/conservation programs and improve their efficacy."

Heyerdahl, E., K. Lertzman, and S. Karpuk. 2007. Local-scale controls of a low-severity fire regime (1750–1950), southern British Columbia, Canada. Ecoscience 14(1):40–47.
www.treesearch.fs.fed.us/pubs/27703

"Historical low-severity fire regimes are well characterized in ponderosa pine and mixed-conifer forests at many sites in the western United States, but not in the southern interior of British Columbia, Canada. We reconstructed a history of low-severity fires (1750–1950) near the northern limit of ponderosa pine and demonstrated that local-scale spatial variation in fire frequency varied with topography and that the intra-ring position of fire scars (a proxy for fire seasonality) varied somewhat with topography but more strongly by tree species. Fires were significantly more frequent on the south than the north aspect (14 versus 24 y mean plot fire intervals, respectively), likely due to differences in fuel type and condition. Frequency did not vary with elevation, although our range of elevation is likely too narrow to detect such variation (227 m). Ring-boundary scars were 5.6 times more likely on Douglas-fir than ponderosa pine, 1.8 times more likely on north than south aspects, and 1.6 times more likely at low than high elevation. Our results confirm the importance of understanding the effect of interspecific variation and topography on cambial phenology and hence intra-ring position before inferring historical fire seasonality from fire scars."

Heyerdahl, E.K., K. Lertzman, and C.M. Wong. 2012. Mixed-severity fire regimes in dry forests of southern interior British Columbia, Canada. Can. J. For. Res. 42(1):88–98.

www.nrcresearchpress.com/doi/abs/10.1139/x11-160

"Historical fire severity is poorly characterized for dry forests in the interior west of North America. We inferred a multicentury history of fire severity from tree rings in Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) – ponderosa pine (*Pinus ponderosa* Douglas ex P. Lawson & C. Lawson) forests in the southern interior of British Columbia, Canada. In 2 ha plots distributed systematically over 1105 ha, we determined the dates of fire scars, indicators of low-severity fire, from 125 trees and inferred dates of even-aged cohorts, potential indicators of high-severity fire, from establishment dates of 1270 trees. Most (76%) of the 41 plots contained fire-scarred trees with a mean plot-composite fire scar interval of 21 years (1700–1900). Most (76%) also contained one or two cohorts. At the plot scale, we inferred that the fire regime at most plots was of mixed severity through time (66%) and at the remaining plots of low (20%), high (10%), or unknown (4%) severity through time. We suggest that across our study area, the fire regime was mixed severity over the past several centuries, with low-severity fires most common and often extensive but small, high-severity disturbances also occasionally occurred. Our results present strong evidence for the importance of mixed-severity fire regimes in which low-severity fires dominate in interior Douglas-fir – ponderosa pine forests in western Canada."

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.R. Erickson, W.L. Harper, and B.M. Wikeem. 1991. Interior Douglas-fir zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 153–116.

www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap10.pdf

"Pure Douglas-fir climax stands are common, and often have an open canopy, because ground fires were common historically, and survival of mature trees with thick bark was favoured. Where crown fires have commonly occurred in the past, there are extensive mixed stands of Douglas-fir and lodgepole pine, often with scattered large Douglas-fir veterans."

"A combination of edaphic and topographic conditions and fire history has led to the development of large grassland communities in parts of the IDF. These grasslands have been modified by grazing of domestic livestock and influenced by reduced fire frequency since the turn of the century."

Iverson, K.E., R.W. Gray, B.A. Blackwell, C. Wong, and K.L. MacKenzie. 2002. Past fire regimes in the Interior Douglas-fir Dry Cool Subzone Fraser variant (IDFdk3). Prepared for Lignum Ltd., Vancouver, B.C. Unpubl. rep.

"We gathered historical fire frequency and data from forty-four sites in the Fraser variant of the dry cool Interior Douglas-fir biogeoclimatic subzone (IDFdk3) to characterize the range of natural variability in historical fire regimes and stand structures. We used existing stand structure data for these sites. Thirty-nine sites were sampled in this study augmented by data from five stands in the study area sampled by Feller et al. (1998).

The study area is characterized by subdued terrain on the Fraser Plateau, with warm, dry summers, frequent summer frosts, cool, dry winters, and mixed Douglas-fir – lodgepole pine forests. We identified three broad strata with differences in forest composition and elevation that appeared to be related to fire history in the study area: 1) lower elevations where most stands are Douglas-fir (Fd Low), 2) middle elevations where Douglas-fir, lodgepole pine and mixed Douglas-fir – lodgepole pine stands occur (FdPl Mod), and 3) higher elevations with predominantly pure lodgepole pine stands (Pl High).

At each of the sample sites we collected six to ten fire scar samples within a 20-hectare area centred on the plot. We collected a total of 265 useable fire scar samples that were cross-dated to determine fire dates for a total of 537 fire scars. We used existing stand structure data and aged 5 trees in each size cohort and 10 trees in the oldest cohort at each plot.

Fire frequency was similar among all three strata with a median Mean Fire Intervals (MFI) of 22 for all strata combined. Median fire frequency at individual plots ranged from 5 to 49 years in the 20 ha plot area. The average MFI for the Pl High stratum (26 years) was longer than for the FdPl Mod stratum (21 years) and Fd Low stratum (19 years), but was not a statistically significant difference.

Current fire-free intervals are two to three times greater than historical MFIs. Eighty percent of plots had a current fire free interval that exceeds the maximum historical fire free interval for that plot indicating that current fire-free intervals across the majority of the landscape have exceeded historical maximums.

Seventy-nine percent of scarred lodgepole pine trees were scarred when they were 6 cm or less in diameter. The majority (75%) of Douglas-fir trees were scarred when they were less than 10 cm in diameter, but 34% were not scarred until they were larger than 14 cm. Thirty-eight percent of lodgepole pine trees were less than 40 years old and 65% were less than 60 years old when they were first scarred. Maximum fire return intervals and age at first scarring indicate that both lodgepole pine and Douglas-fir sometimes survived a fire before scarring, but Douglas-fir is more likely to do so.

The Pl High stratum showed the most evidence for a component of stand replacing events in the disturbance regime with four of the eight plots sampled being relatively even-aged. Nearly all trees are lodgepole pine. Mean historical stand densities (540 stems/ha of trees established before 1900) were about half of that currently found in our plots (1186 stems/ha for trees ≥5 cm DBH) and one-third of that in a small representative sample of all stands (1569 stems/ha for trees ≥5 cm DBH) in this stratum. Dead wood, representing stems that might have added to historical stand densities, is not abundant (average 136 stems/ha).

The majority of plots in the FdPl Mod stratum were multiple-aged (25 of 29 plots). One plot appeared to have two cohorts, two plots were single aged with scattered vets, and one plot was even-aged (PSP387). This range of stand structures suggests a mixed severity fire regime dominated by low severity fire. Stands ranged from pure Douglas-fir to pure lodgepole pine and mixtures of both. Mean historical stand densities (421 stems/ha of trees established before 1900), are about one-quarter of that currently found in our plots (1758 stems/ha for trees ≥5 cm DBH) and one-third of that in a representative sample of all stands (1371 stems/ha in this stratum for trees ≥5 cm DBH). Dead wood is not abundant in current stands (average 170 stems/ha). Large Douglas-fir trees are much less abundant on the landscape today than they were historically.

All plots in the Fd Low stratum were multi-aged, dominated by Douglas-fir and often showed a regeneration pulse in the late 1800's. Average historical stand density was 499 stems/ha in 1860, jumped to 1582 stems/ha by 1900 and is 2487 stems in our sample and 2902 for a small sample of managed and unmanaged stands (n=5). Dead wood is not abundant (average 120 stems/ha).

Modelled fire extent was about 2000–3000 ha for a one-week burning period with average weather under both current and historical fuels. Much larger fire sizes are possible under more extreme weather conditions.

We identified two fire regimes: a predominantly understory fire regime in the Fd Low stratum and a mixed severity fire regime in the FdPl Mod and Pl High strata. Within the mixed-severity fire regime, severity within individual fires varied between low severity surface fires and stand-replacement. Based on the sampling and observations within the each plot, the dominant component of both fire regimes appeared to be low severity surface fires. Some patches of even-aged stand structure provided evidence for some patches of higher severity fire.

While grass fuels were likely the dominant fuel type in all strata under historical conditions, tree mortality from other causes such as mountain pine beetle, Douglas-fir beetle, or root diseases likely created small patches of dead and downed material that provided surface fuels for increased overstory mortality in a subsequent fire. These patches likely made up the higher severity component of the mixed-severity fire regime found at some sites.

Current forests with dense regeneration, multi-layered stands and fuel accumulations indicate an overall increased fire hazard on the landscape that is a significant management concern. The impacts of this risk are potentially wide reaching and include biological risk (loss of productivity and biodiversity), economic risk (reductions in annual allowable cut and previous silviculture investments) and social risk (direct damage to private property, community instability and job losses)."

Jordan, G.J., M.-J. Fortin, and K.P. Lertzman. 2008. Spatial pattern and persistence of historical fire boundaries in southern interior British Columbia. Environ. Ecol. Stat. 15(4):523–535. www.springerlink.com/content/a6706765532r2646/

"Recent ecosystem and fire management research aims to quantify, model and understand historical fire disturbances focusing on their frequency, size and distribution. Less attention, however, has been paid to fire boundaries and their location on the landscape. Our study presents a spatial method to quantify the location, pattern and persistence of historical fire boundaries using tree ring fire scar data in the lower Stein watershed (British Columbia). Data from *Pinus ponderosa* and *Pseudotsuga menziesii* collected in 35 one-hectare plots over a 412-hectare study area were analyzed for the period between 1879 and 1947 using local spatial statistics and boundary detection techniques. Results of the analysis using local spatial statistic Moran's I showed significant clustering of boundaries near topographic breaks. To determine and test whether fire boundaries between plots were persistent, we used boundary detection methods and developed a spatially restricted randomization test. The results revealed that out of 86 possible boundary links, 8 were significantly persistent ($P < 0.025$) while another 8 were significantly rare ($P < 0.025$). These spatial methods can help determine the historical spatial configuration of persistent boundaries and can be used to maintain natural forest dynamics."

Klenner, W., R. Walton, A. Arsenault, and L. Kremsater. 2008. Dry forests in the Southern Interior of British Columbia: historic disturbances and implications for restoration and management. For. Ecol. Manag. 256(10):1711–1722. www.sciencedirect.com/science/article/pii/S0378112708002260

"We critically examine the hypothesis that dry forests in southern British Columbia evolved in the context of a low-severity fire-dominated disturbance regime, that fire suppression has led to ecological conditions which are radically different from the past, and that 'restoration' initiatives are required to re-establish former ecological conditions. Four sources of information were used to infer historic disturbance regimes and forest condition and to quantify the nature of disturbance since the early 1900s: (1) patterns of annual and seasonal weather and lightning strikes, (2) topographic variability, (3) records of wildfire, insect attack, and timber harvesting practices, and (4) early systematic forest surveys.

Our analyses consistently indicate that historic natural disturbances were likely diverse and episodic at multiple spatial and temporal scales. High seasonal and annual variability in weather and the number of lightning strikes in complex topography suggest that a widespread low-severity fire regime is very unlikely, with a mixed-severity disturbance regime more consistent with our analyses. Although the nature of disturbance has changed from one largely dominated by fire and insect attack historically to harvesting and insect attack since 1950, the area disturbed annually has not diminished. Several interacting factors including climate, extensive fires coincident with European settlement, harvesting, fire suppression and insect attack have been key drivers in creating the conditions observed today. A complex, mixed-severity disturbance regime creates uncertainty about what represents 'natural' forest conditions, or what the target conditions for restoration activities are if the objective is to 'restore natural conditions.' We conclude that dry forest ecosystems in British Columbia typically experienced mixed-severity disturbance regimes that included fire, bark beetles and defoliators. Trying to 'restore' these forests with applications of frequent, low-severity fire is not an ecologically sound objective over large areas. Landscape management should focus on maintaining forest heterogeneity that would have existed historically under a mixed-severity disturbance regime."

Lloyd, D., K. Angove, G. Hope, and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 23. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh23.htm

"Much of the IDF landscape is occupied by mature forests of pure Fd [Douglas-fir]. Where recent crown fires have occurred, mixed Fd and Pl [lodgepole pine], or Fd and Py [ponderosa pine], are common." "A combination of edaphic and topographic conditions, and fire history, has led to the development of large grassland communities in parts of the IDF."

Low, D.J. 1988. Effects of prescribed burning on non-target wildlife species associated with fire prone ecosystems in the southern interior of British Columbia. In: Wildlife and range prescribed burning workshop proceedings. Oct. 27–28, 1987, Richmond, B.C. M.C. Feller and S.M. Thomson (editors). Univ. British Columbia, Fac. For., Vancouver, B.C., pp. 185–196.

Two sites near Kamloops have fire frequencies of 7.2 and 10.5 years, respectively. The first site experienced fires between 1774 and 1933 inclusive but none since then. The second site had fires between 1672 and 1900 inclusive but none since then.

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 1. Very dry climatic region. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

In the IDFb1 [IDFdk1], in the eastern part of the study area, "past fires and logging have had a significant influence on the existing forest and understory vegetation composition. Even-aged stands of Pl [lodgepole pine] and sometimes F [Douglas-fir] are typical of this variant. Crown fires were common and today extensive areas are covered primarily by young and maturing seral Pl stands."

In the IDFa [IDFxw], in the eastern half of the study area, "past fires, logging and grazing have had a significant influence on the existing forest and understory vegetation composition. Frequent underburning or ground fires were common and affected the structural development of the understory, while leaving the fire resistant F and Py [ponderosa pine] in the main canopy relatively undisturbed. Uneven-aged stands are common as a result of more recent selective logging."

In the PPBGd [PPxh2], in the northeastern part of the study area, "past fires, logging and grazing have had a pronounced influence on the existing forest and understory floristic composition. Frequent underburnings, or ground fires, were common and have affected the structural development of the understory, especially the F regeneration, but have not significantly affected the fire resistant main tree canopy of Py and F. Uneven-aged stands are becoming more common now as a result of selection logging and the suppression of fires."

In the PPBGf1 [PPxh], at lower elevations near Princeton, "past fires, logging and grazing have had a significant influence on the existing forest and understory vegetation composition. Frequent underburning or ground fires have affected the structural development of the understory, but have not significantly affected the main tree layer of fire resistant F and Py. Uneven-aged stands are now more common as a result of selection logging and the suppression of fires."

In the PPBGf2 [PPxh1], at lower elevations near Hedley and the lower Ashnola, "past fires, logging and grazing have had a significant influence on the existing forest and understory vegetation composition. Frequent underburnings, or ground fires, were common and have affected the structural development of the understory. The factors affecting ecosystem development are similar to PPBGf1 [PPxh], except the soil development processes are more weakly expressed because of the drier climate."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 2. Dry and subcontinental climatic regions. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

The IDFd [IDFdk2] is in the southwestern and northeastern parts of the study area. "Past crown fires were common and today extensive areas are young and maturing stands of Pl [lodgepole pine]. Fires have also had a significant influence on the understory vegetation composition resulting in a high coverage of *Calamagrostis rubescens* under seral Pl stands. With increased organic accumulation, *Paxistima myrsinites* increases in coverage."

The IDFc [IDFxh1] is limited to the southwestern part of the study area. "Past fires, logging and grazing have significantly influenced the existing forest and understory vegetation composition. Frequent underburning or ground fires were common and affected the understory structural development, but not usually the main canopy of fire resistant F [Douglas-fir] and Py [ponderosa pine]."

Parminter, J.V. 1978. Forest encroachment upon grassland range in the Chilcotin region of British Columbia. MF essay. Univ. British Columbia, Dep. For., Vancouver, B.C.

"The encroachment of forest trees upon grasslands in western North America has been variously attributed to the exclusion of periodic wildfires, the effects of domestic grazing, and possible climatic change. The presence of forest trees on grassland range interferes with the movement of domestic stock and leads to a decline in forage production. The encroachment of Douglas-fir regeneration upon grassland range on Dester Ridge, in the eastern Chilcotin region of British Columbia, was examined to determine if the distribution of the trees on the grassland formed any spatial or temporal patterns.

Six belt transects were established on the grassland along Dester Ridge and the adjacent forest was examined as well. The density (number per unit area) of encroaching trees in the transects varied from nil to heavy and variation in the density of trees was noted within as well as between transects. No relationship was found between the age of individual trees and their distance from the forest edge. The trees began to become established on the grassland in 1931, their numbers peaked in 1951, and the number of trees established annually has declined since then. Slightly more than one-half of all trees found on the grassland became established between 1943 and 1952.

Analysis of fire scars on the old-growth trees near the forest–grassland boundary revealed a series of 17 fires between 1759 and 1926 [MFI=10.4 years]. The absence of fire since 1926 has aided the process of forest encroachment and has allowed changes to take place in the structure and age-class distribution of the forest stand.

Specific data on grazing use and effects are not available but grazing by domestic stock has likely reduced ground cover levels, exposed mineral soil, and reduced competition between grasses and herbs and tree seedlings. No correlation was found between available climate data and the temporal pattern of the numbers of encroaching trees established each year. It is felt that site microclimate as determined by topographic position and local topography is the major factor influencing the distribution of the encroachment.

On sheltered sites with a heavy grass cover, tree regeneration will be kept out by high levels of competition for growing space, water, and nutrients. Sites which are very exposed to desiccating winds and insolation are not likely to support many trees due to available soil moisture deficits leading to tree mortality. The advance of the forest will therefore take place mainly on sites which fall between these two extremes.

The initial advance of the forest depends on seed from the parent stand and on favourable microsite conditions but continued advance will occur as the invading trees bear seed and ameliorate the microclimate. While this process appears to be extremely slow, it may be deemed necessary to counteract this forest advance in certain locations where the problem is most severe and the consequences most profound."

Parminter, J. 1991. Fire history and effects on vegetation in three biogeoclimatic zones of British Columbia. In: Fire and the environment: ecological and cultural perspectives. Proc. Int. Symp. March 20–24, 1990, Knoxville, Tenn. S.C. Nodvin and A. Thomas (editors). U.S. Dep. Agric. For. Serv., Asheville, N.C. Gen. Tech. Rep. SE-69. pp. 263–272. www.srs.fs.usda.gov/pubs/gtr/gtr_se069/gtr_se069-section04.pdf

"The different fire regimes present in the province of British Columbia are well-illustrated by the Coastal Western Hemlock, Boreal White and Black Spruce, and Ponderosa Pine Biogeoclimatic Zones. Fires are variable in type, intensity, severity, effects, size, and interval. In the first two biogeoclimatic zones, stand replacement and/or partial stand replacement fires occur. Surface fires that maintain open forests with grassy understories are the historic norm in the Ponderosa Pine Zone.

Fire histories and fire effects have been determined for all three zones. In the Coastal Western Hemlock Zone the emphasis has been on fire history, stand establishment, and prescribed burning. Ecosystem-specific guides describing the type of fire suitable for silvicultural site preparation are widely available. Post-fire vegetation successional pathways have been developed for the Boreal White and Black Spruce Zone and are used to predict probable fire outcomes.

In recent times, the adverse implications of fire exclusion have been recognized in ecosystems such as those found in the Ponderosa Pine Zone. The reintroduction of fire through prescribed burning serves to address the problems and meet several resource management objectives."

Parminter, J. and P. Daigle. 1999. Fire in the dry interior forests of British Columbia. In: Helping the land heal conference—ecological restoration in British Columbia. Conf. proc. Nov. 5–8, 1998, Victoria, B.C. B. Egan (compiler and editor). BC Environ. Netw. Educ. Found., Vancouver, B.C., pp. 220–223.

"By studying fire-scarred trees and stumps we know that [understorey] fires occurred between every 7 to 22 years in these forests. The following table shows fire periodicities for several sites. The mean fire return intervals (MFRI) are based on the number of known fires between the first and last fire dates.

Site	Biogeoclimatic unit	First fire	Last fire	MFRI
Koocanusa Lake (East Kootenays)	PPdh2	1813	1940	6.7
Battle Bluff (near Kamloops)	BGxh2	1757	1913	9.7
Riske Creek (Chilcotin)	IDFdk4	1759	1926	10.4
Pothole Creek (near Merritt)	IDFdk1	1693	1967	13.0
Chasm (Cariboo)	IDFdk3	1791	1911	13.3
Alex Fraser Research Forest (Cariboo)	IDFdk3	1754	1915	13.4
Gang Ranch (Chilcotin)	IDFxm	1678	1958	14.0
East Kootenay (location unknown)		1729	1908	14.9
Dewdrop Range (near Kamloops)	PPxh2	1542	1967	19.3
Canal Flats (East Kootenays)	IDFdm2	1628	1937	22.0

On sites where the fire scar record is especially long, the mean fire return interval may be artificially lengthened due to sampling statistics. More very old fire-scarred trees would be needed to reveal a nearly complete record of fires during the 1500s and 1600s. This is important because not every fire leaves a scar, even on a tree that has an existing basal wound, so the record is considered to be a minimum indication of fire events and frequencies. The actual number of fires was likely greater in most cases."

Pollack, J., H. Quesnel, C. Hauk, and H. MacLean. 1997. A quantitative evaluation of natural age class distributions and stand replacement intervals in the Nelson Forest Region. Vol. 1. B.C. Min. For., Nelson For. Reg., Nelson, B.C. Tech. Rep. TR-015.
www.for.gov.bc.ca/hfd/pubs/RSI/FSP/Nelson/RNE_TR-015.htm

Using the corrected Forest Inventory Planning (FIP) age-class data, estimated stand replacement intervals ranged from 111 years in the IDFdm2 to 121 years in the IDFdm1.

Riccius, E. 1998. Scale issues in the fire history of a fine grained landscape. MRM essay. Simon Fraser Univ., School Resourc. Environ. Manag., Burnaby, B.C.
www.collectionscanada.gc.ca/obj/s4/f2/dsk2/ftp03/MQ37620.pdf

"The scale of an ecological study determines the ability to detect patterns and processes on the landscape. I demonstrate the importance of a multiscale analytical framework, using evidence of historical surface fires in a dry interior forest of ponderosa pine and Douglas-fir in southwestern British Columbia. The study area comprises 28 ha in a set of seven riverside terraces along the Lower Canyon of the Stein River. I use three spatial scales within a narrow range to test five alternative hypotheses about factors influencing fire regimes and their spatial distribution. The coarsest scale encompasses the entire study area and examines regional climate as a factor influencing fire. The intermediate scale is at the level of riverside terraces ranging from 2 ha to 16 ha. This scale analyses the influence of local topographic features such as, the river and rocky ridges which separate the terraces from one another as a factor influencing fire. I defined the finest scale as 2-ha sub-terrace units which includes the small terraces. The factors influencing fire at this scale include fuel continuity and fuel moisture. The first two hypotheses use the parameters mean fire interval, seasonality and extent, to distinguish between coarse scale factors and intermediate and fine scale factors that influence the fire regime. The remaining three hypotheses use the synchrony in fire dates to test for coarse, intermediate and fine scale factors, that influence the spatial distribution of fire.

Fire history data were collected using a fine scale sample design which provided an even spatial distribution of samples through the study area. I prepared and crossdated fire scars according to standard dendrochronological techniques. For statistical purposes, I identified a subset of fire dates which fall within a Period of Reliability from 1863 to 1936. Most analysis are also conducted using a longer record (1748 to 1972) to maximize the temporal depth of the data.

Mean fire intervals, seasonality and extent, determined from 102 samples, were similar through the study area at each scale indicating that coarse scale factors dominate the regime. Mean fire intervals were 5 years for the whole study area, and ranged from 5 to 28 years with a grand mean of 14 years at the scale of 2-ha sub-terrace units. Seasonality of fires was also similar among fire scarred samples for each scale of analysis. Extent was analysed only within the study area, recognizing that many fires probably also burned outside the study area. Most fires were small. Seventy-five percent of fires within the Period of Reliability recorded evidence on only one or two sub-terrace units, covering 2 or 4 ha. The largest fire burned 24 ha.

The spatial distribution of fires in the study area seems to be driven by factors at the finest scale. Synchrony in fire dates was not observed at any scale of analysis which reinforces that fires were small. Fires were random in their spatial locations among the 2-ha sub-terrace units. At the finest scale, 21% of fires burned in a disjunct pattern; most of these fires occurred on 2 sub-units only. These results provide evidence that fuel continuity and moisture play a key role in the spatial distribution of fire.

Management practices for dry interior Douglas-fir and ponderosa pine forests in southwestern British Columbia should reflect the natural disturbance regime. A selection silviculture system is appropriate for timber extraction to reflect the patchy but fine-grained nature of fire as a disturbance. For management of protected areas, historical stand structure should be restored through vegetation management and prescribed fire."

Smaill, G. 1980. Seasonal effects of fire on ponderosa pine/bunchgrass and Douglas-fir/pinegrass ranges. Unpubl. term pap. Washington State Univ., Pullman, Wash.

Experimental plots were established above Tranquille, B.C., in the Lower Dewdrop Range in 1978 and in the Upper Dewdrop Range in 1979 to study the impacts of fire on forested range. The Lower Dewdrop, in the PPxh2, contained ponderosa pine and Douglas-fir in equal proportions. Surface fire history determined from fire scars indicated 23 fires between 1542 and 1967 inclusive, for a mean fire interval of 19.3 years. The shortest interval was 5 years (1839 to 1845) and the longest was 51 (1643 to 1692). The Upper Dewdrop, in the IDF, was dominated by Douglas-fir. Surface fire history determined from fire scars indicated 24 fires between 1775 and 1976 inclusive, for a mean fire interval of 8.8 years. The shortest interval was 1 year (1879 to 1880) and the longest was 26 (1899 to 1925). The two sites had only one fire in common, in 1899. Tree age class distributions suggest that it was a major event compared to more recent fires on the Lower Dewdrop in 1927 and 1967.

Spilsbury, R.H. and E.W. Tisdale. 1944. Soil-plant relationships and vertical zonation in the Southern Interior of British Columbia. Scientific Agric. 24(9):395–436.

Above Tranquille, B.C., repeated fires have favoured lodgepole pine and trembling aspen at the expense of Douglas-fir, but many old individuals of this species have survived due to their thick bark.

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"Climax vegetation on zonal sites in the IDF Zone is a Douglas-fir forest, often with a few lodgepole pine in the forest canopy. The Douglas-fir trees are typically multi-sized and multi-aged, and Douglas-fir regeneration is usually abundant in the understory except in the driest parts of the zone. Most stands are characterized by widely spaced, large, old Douglas-fir 'vets' that have survived past ground fires. The distribution of tree seedlings is typically patchy, in response to canopy gaps, ground-fire patterns, and past surface disturbances that have created mineral soil seedbed." "Seral forests that develop after a canopy fire on zonal sites in the IDF Zone are usually dominated by lodgepole pine and, locally, by trembling aspen or ponderosa pine. Lodgepole pine forests are extensive in the cool and moist parts of the zone (IDFdk and IDFmw subzones). However, lodgepole pine is seldom present on zonal sites in the warmest and driest subzones (IDFxw and IDFxm) where Douglas-fir forests return directly after a fire, following a grass-dominated stage, or (in the IDFxw) after a ponderosa pine-dominated stage. Grasslands and non-forested wetlands are common in the IDF Zone. Small grasslands occur locally on dry, south-facing slopes. Larger grasslands occur on the plateau, especially near the Fraser River valley, where fire history or soil factors (salinity) have prevented the establishment of forests."

"The IDFdk is by far the largest subzone (about 12 967 km^2) of the IDF in the Cariboo Forest Region. It occurs on the level to gently rolling plateau landscapes above the valleys of the Fraser, Chilcotin, and Chilanko rivers. The IDFdk extends about as far north as Williams Lake and as far west as Tatla Lake. It has the coldest climate of the five IDF subzones in the Cariboo Forest Region. Climax forests on zonal sites of the IDFdk typically have a multi-aged Douglas-fir-dominated canopy, abundant Douglas-fir regeneration with a very patchy distribution, and a pinegrass-dominated undergrowth. Douglas-fir trees usually include scattered large 'vets' that have survived previous wildfires."

"The IDFxm occurs primarily in the Fraser and Chilcotin river valleys south of about Alexandria and east of Redstone, respectively. In the Fraser River valley, south of the confluence with the Chilcotin River, it occurs on middle and upper valley slopes. North of the confluence with the Chilcotin River, it includes lower valley slopes as well. In the Chilcotin River valley it occurs on middle and upper valley slopes near the Fraser River but includes all valley slopes near Alexis Creek." On zonal site series "the Douglas-fir stands have a moderately closed canopy and are single- to multi-storied, depending in part on the history of wildfires that have destroyed small but not larger stems."

Strang, R.M. and J.V. Parminter. 1980. Conifer encroachment on the Chilcotin grasslands of British Columbia. For. Chron. 56(1):13–18. http://pubs.cif-ifc.org/doi/abs/10.5558/tfc56013-1

"Detailed quantitative examination of a grassland/forest ecotone near Williams Lake, B.C. showed that a combination of fire, grass competition and subtle micro-site determinants of soil moisture availability appear to be the factors influencing tree encroachment most strongly. Historically fire has inhibited tree establishment on the grasslands – between 1759 and 1926 the fire interval approximated 10 years. Presumably because of heavy grazing, no severe fires have burned the area since 1926. Conifer encroachment began in 1931 and virtually ceased in 1972."

Taylor, G.B. 1983. Fire history of a small lodgepole pine–Douglas-fir stand in Manning Park, British Columbia. BSF thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.

"The fire history of an 82 ha forest area in Manning Park was determined. The forest is 60 percent lodgepole pine (*Pinus contorta* Dougl.) and 40 percent Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Basal fire scars were used to date fires. Fire years were 1854, 1881, 1890, 1897, 1915 and 1935. All fires were low intensity ground fires. The stand is many aged and age class data correlates poorly with fire dates. The stand appears to have maintained itself in an open condition since 1850. Douglas-fir is beginning to dominate the youngest age classes and mature lodgepole pine is undergoing heavy mortality due to attack by mountain pine beetle." The Mean Fire Return Interval for the period 1850–1940 was 15.25 years.

Tisdale, E.W. 1950. Grazing of forest lands in Interior British Columbia. J. For. 48(12):856–860.
www.ingentaconnect.com/content/saf/jof/1950/00000048/00000012/art00009

Repeated fires have favoured lodgepole pine, trembling aspen, and willow at the expense of Douglas-fir, which is very limited in area. Lodgepole pine can be very persistent where Douglas-fir is scarce, but the trembling aspen and willow usually last only one generation. Forest encroachment onto grasslands appears to represent primarily the return of trees to areas previously deforested by repeated fires.

Tisdale, E.W. and A. McLean. 1957. The Douglas-fir zone of southern interior British Columbia. Ecol. Monogr. 27(3):247–266.
www.jstor.org/pss/1942185

"The recent history of the Douglas-fir zone in interior British Columbia is one in which fire, insects, lumbering, and grazing have all been important. Early historical records and studies of past burns indicate that fire has long been common in this zone. Fires caused by lightning occur at the present time and presumably were a factor in the past. Records of the Kamloops Forestry District, which includes large areas of the Douglas-fir zone indicate that lightning caused from 15 to 43% of all forest fires during the period 1952 through 1955. Man-made fires probably have been a normal occurrence for a long time, for there is evidence that the native Indians were accustomed to setting fires in both grasslands and forest areas in order to make better hunting grounds…. The incidence of fires evidently was increased temporarily with the coming of the white man, particularly during the period 1870 to 1890, when railroad construction and prospecting were most active. The importance of fire as a disturbing agent in recent times is indicated by data for the Tranquille Provincial Forest reported by the B.C. Forest Service…. During the period 1850–1931 there were 22 known fires which burned 57% of the area. Approximately two-thirds of the fire damage was done during the period 1870–1890. The incidence and size of fires has declined during the past few decades with further settlement of the country and the development of better fire control facilities."

Tisdale, E.W., A. McLean, and S.E. Clarke. 1954. Range resources and their management in British Columbia. J. Range Manag. 7(1):3–9. http://digitalcommons.library.arizona.edu/objectviewer?o=http%3A%2F%2Fjrm.library.arizona.edu%2FVolume7%2FNumber1%2Fazu_jrm_v7_n1_3_9_m.pdf

Repeated fires have favoured lodgepole pine and trembling aspen at the expense of Douglas-fir. Areas dominated by trembling aspen usually have better forage cover than those with conifers, while sites occupied by dense young stands of lodgepole pine or Douglas-fir produce almost no forage.

Wikeem, B.M. and T.J. Ross. 2002. Plant succession in the Rocky Mountain Trench: influence of historical factors. Rangelands 24(6):17–20. http://digitalcommons.library.arizona.edu/objectviewer?o=http%3A%2F%2Frangelands.library.arizona.edu%2FVolume24%2FNumber6%2Fazu_rangelands_v24_n6_17_20_m.pdf

"Historically, lightning-caused fire has been prevalent in the Ponderosa Pine and Interior Douglas-fir zones and is regarded as a natural part of the environment. Low-intensity ground fires, returning at 5–50 year intervals, maintained ponderosa pine and Douglas-fir forests in the Trench as a mosaic of grassland, open forest, and dense forest."

"Aboriginal fires also played a role in shaping and maintaining plant communities in the Trench historically. Evidence from the Flathead region of the Pacific Northwest U.S. indicates that the introduction of horses considerably intensified native burning, especially as horse herds became larger. Although the Kootenay Indians respected fire, early narratives suggest that they deliberately set forest fires to create horse pasture."

"Both the direct effects of logging, and the subsequent fires that followed, contributed to opening up large areas of range for cattle, horses, and wildlife throughout the southern part of the Trench. Numerous fires occurred between 1914 and 1931 as the litter of limbs, treetops and broadaxe chips dried and became extremely flammable. Some fires, like the fire of 1914, started in the logging camps but steam locomotives throwing out sparks along the railway ignited others. Many of these fires consumed large volumes of standing timber and covered extensive areas of the landscape. The last large fire in 1931, for example, burned about 81,000 ha (200,000 ac) of forestland alone."

Wong, C.M. 1999. Memories of natural disturbances in ponderosa pine – Douglas-fir age structure, southwestern British Columbia. MNRM essay. Simon Fraser Univ., School Resourc. Environ. Manag., Burnaby, B.C. http://research.rem.sfu.ca/theses/WongCarmen_1999_MRM255.pdf

"Forest heterogeneity is important for maintaining biodiversity. Maintaining this heterogeneity requires an understanding of historical disturbance regimes and their structural consequences. In dry, mixed conifer forests such as those in the inland western United States and British Columbia south of 52°N, disturbance regimes have been characterized as mixed-severity – a combination of low-, moderate- and high-severity disturbances. Thus in these forests, disturbance severity, the impact of an event on vegetation, is an important influence on forest structure. The relative roles of different severity disturbances are rarely quantified because it is challenging to sample and interpret such influences. The overall objective of this thesis is to use the age structure of a ponderosa pine (*Pinus ponderosa*) [illegible] Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) forest in southwestern British Columbia to understand the relative influence of low-, moderate- and high-severity disturbances on tree establishment and mortality."

"The second chapter explicitly investigates my overall objective. I use spatial and temporal patterns in tree establishment to characterize the severity of the disturbance regime over the lower Stein Valley, British Columbia. Since there is evidence that dry, mixed conifer forests in the western United States have been modified by fire suppression, I also examine whether forest dynamics have changed since aerial fire suppression began in the 1950s in British Columbia. I attempt to derive management recommendations from my results by describing the range of natural variability in age structure."

Wong, C. 2000. Natural disturbance regimes in the Cariboo region: what is known to guide forest management? Prepared for Lignum Ltd., Vancouver, B.C. Unpubl. rep.

"In general, the quality and quantity of data on past natural disturbance regimes are poor in the Cariboo. Most data are from studies which have not been peer reviewed, meaning the quality of the data is uncertain. Not enough data exists to describe the historical temporal and spatial variability in disturbance regimes over different biogeoclimatic variants and topographic positions in the Cariboo Forest Region and in Lignum's IFPA area. The data that do exist illustrate that there is temporal and spatial variability in forest dynamics and disturbance regimes in the Cariboo. Some conclusions about past natural disturbance regimes were possible:

1. Small shifts in climate (e.g., 2 - 4°C increase in temperature) can drive variability in forest composition and disturbance regimes over long time scales (e.g. > 1000s of years).
2. Historical patterns in temperature and precipitation over the last 500 years have not been reconstructed yet from tree rings in the Cariboo.
3. Tree encroachment into grasslands since the 1960s, particularly in wet sites and on northern aspects, has decreased grassland by approximately 30% over areas of the Fraser and Cariboo Basin ecosections. Open, closed and aspen forests varied in whether they increased or decreased.
4. The frequency of low-severity fires in 14 Cariboo stands varied over space. Between 1717 and 1900, the mean fire interval ranged from 7 to 29 years, median 15 years. Including fires after 1900, the median MFI increased to 21 years, suggesting fire exclusion has occurred in the Cariboo. The last fires in the stands occurred 1911 - 1968.
5. On the Chilcotin Plateau, 9 – 24% of a large SBPSxc and MSxv landscape was likely cumulatively burned by small (< 120 ha) and large (> 1000 ha) high-severity fires over any given 20 year period between 1850-1950. This is similar to the SBSmk1 in the Prince George Region but peak periods of disturbance differed. Fire creates more complex spatial patterns on the sub-boreal landscape than traditional clearcutting; e.g. refugia from fires in the 1930s and 1950s, comprise 3-15% of burned areas and were 1-73 ha in size in the SBSmk1 in the Prince George Region.

6. There are not enough data to determine historical insect and disease disturbance regimes in the IFPA area. Patterns in tree rings indicate that widespread, high-severity outbreaks of spruce bark beetle occurred infrequently in the past (1720s, 1810-1820, 1960-1980s) in the Prince George region.
7. The IDF in the IFPA area east of the Fraser River has the potential to be relatively frequently disturbed every year to every 40 years by either fire or extreme wind events.
8. Traditional burning for maintaining meadows and open forests did occur in early spring around Canoe Creek, southern part of the IFPA area east of the Fraser River."

MONTANE SPRUCE BIOGEOCLIMATIC ZONE

Braumandl, T.F. and M.P. Curran (compilers and editors). 2002. A field guide for site identification and interpretation for the Nelson Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 20. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh20.htm

The MSdk is found on "mid slopes in the Rocky Mountain Trench south of the Spillimacheen River; valley bottoms and lower slopes of valleys on the eastern flanks of the Purcell Mountains south of the Spillimacheen River; and valley bottoms and lower slopes in the Rocky Mountains south of the Kickinghorse River." "Extensive stands of seral Pl [lodgepole pine] exist in the MSdk because of widespread wildfires. The mountain pine beetle (*Dendroctonus ponderosae*) has devastated some areas, resulting in extensive salvage logging, especially in the Flathead River drainage." "The extensive fire history has maintained a predominance of early seral wildlife species."

The MSdm1 occupies "mid slopes in the Okanagan Highlands and in the Midway Range of the Monashee Mountains." "An extensive history of wildfires has led to a predominance of Pl stands and few climax stands. Mountain pine beetle infestations are widespread. Extensive clearcutting has resulted in a 'fragmented' forest in many areas of the MSdm1." "The extensive fire history has maintained many early seral wildlife species."

Cochrane, J.D. 2007. Characteristics of historical forest fires in complex mixed-conifer forests of southeastern British Columbia. MSc thesis. Univ. British Columbia, Dep. Geog., Vancouver, B.C. https://circle.ubc.ca/handle/2429/31644

"Forest fires in southeastern British Columbia are considered the dominant natural disturbance to have shaped forest structure. In the mixed conifer montane forests of the Dry Cool Montane Spruce (MSdk) biogeoclimatic subzone, we have limited understanding of the characteristics of fire which have resulted in current forest structure. A better understanding of fire in these forests is needed to improve forest management and ecosystem restoration strategies which seek to emulate natural disturbance. To assess the historic role of fire in mixed conifer forests and to test the null hypothesis that fires do not vary spatially or temporally, this study uses cambial fire scars to analyze the historic frequency of fire in 20 stands that are statistically representative of complex, mixed-conifer forests in the southern Rocky Mountain Trench of British Columbia. Determining the date of cambial injury on a tree is an important objective of ecological research that determines the timing of disturbances such as fire, tree falls, or human modification of trees." "Spatial variation in fire is an important driver of forest heterogeneity at the stand and landscape scale. Using cambial fire scars on trees sampled at 20 study sites, I determined that fire frequency varied considerably between and among studied plots. I expected fires would be more frequent in plots with southern aspects than northern aspect plots. Instead, using logistic regression, I found fires to be more frequent on plots with northern aspects plots than southern aspect plots. Plot elevation, slope angle and solar radiation significantly influenced fire frequency, while plot aspect and latitude did not. Differences in season of fires were predominantly the result of differences in phenology between the two most commonly sampled tree species, Douglas-fir (*Pseudotsuga menzeisii* var *glauca* (Beissn.) Franco) and western larch (*Larix occidentalis* Nutt.). Temporally, fire was most frequent during the time period of documented European settlement and the least frequent during the modern fire suppression period. My research results have important implications for forest management strategies which emulate natural disturbance to promote ecological resilience. Historically, fire occurred in the complex montane forests at much higher frequency than is currently classified using the Natural Disturbance Types (NDT). As a result, forest management strategies are likely preventing the occurrence of low- to moderate-severity disturbances in these forests, reducing their ecological resilience. Future management strategies should incorporate the variability observed in this study at the stand and landscape scales and return low- to moderate severity disturbances to these stands more frequently. Ecosystem restoration in these forests should be prioritized on stands that have deviated the most from the historic frequency of fires; particularly in stands which are at lower elevations and closer to valley bottom of the Rocky Mountain Trench."

Cochrane, J. and L. Daniels. 2007. Ask your neighbour: a tale of two plots. Spatial variation in historic fire regimes of southeastern B.C. Univ. British Columbia, Dep. Geog., Vancouver, B.C. www.for.gov.bc.ca/hfd/library/FIA/2007/FSP_Y071167a.pdf

"A total of 17 samples were collected from both plots and 16 samples were statistically cross-dated using COFECHA and one was visually cross-dated. The number and year of occurrence of fires varied between the two plots. The Warm plot was recording fires from 1718 to 2006 with a total of 12 fire years, while the Cool plot was recording fires from 1629 to 2006 with nine fire years. Three fire years were common to both plots: 1722, 1757 and 1831. The most recent fire year was 1940 at the Cool plot, making the time since last fire 66 years. The last fire at the Warm plot was in 1903, making the time since last fire 103 years. The interval between the successive fires ranged from two to 109 years. The minimum intervals were two and five years and the maximum intervals were 103 and 109 years for the cool and warm plots respectively."

"A lack of concurrent fire years between the two plots was surprising. Despite being separated by only 545 meters the two plots shared only three of 23 fire years. Spatial variation in fire regimes can be the result of many factors including: species composition, and natural or topographical barriers to fire spread. These two plots differed in aspect over a small horizontal distance caused by a depression in elevation and the occurrence of a small lake to the north of the plots. Increased soil moisture was observed between the two sites, influencing both the species composition and the fuel moisture content and thus potentially limiting the direct spread of fire from one plot to the next. The existence of such a topographic shift could also act as a barrier to fire spread, reducing the number of shared fire events. The low concurrent number of fires between these two plots lends support to the hypothesis that changes in local topography are driving the spatial variation in fire and stand structure that is observed in these forests."

Cochrane, J. and L.D. Daniels. 2007. Quantifying spatial variation in fire regimes in MSdk stands found in the southern Rocky Mountain Trench: southern versus northern aspects. 6th N. Am. For. Ecol. Workshop, June 2007, Vancouver, B.C.

www.for.gov.bc.ca/hfd/library/FIA/2008/FSP_Y082167e.pdf

"Knowledge of the natural disturbance processes affecting forested landscapes is essential to any forest management plan, whether the objective is timber production, wildlife conservation or wilderness management. Spatial variation in forest fire regimes is an important source of environmental heterogeneity and species diversity. We examined topography as a control on spatial variation in the Montane Spruce dry–cool (MSdk) conifer forests of southeastern British Columbia by stratifying stands by aspect (warm: 165° – 285° and cool: 345° – 105°) and randomly selecting twenty plots with similar stand structure from across the landscape. Each plot, one hectare in size, was sampled for fire history by collecting an average of nine fire scarred trees, stumps or logs. No fire scar data was discovered at two of the twenty plots. For the remaining 18 plots, dates and seasons were assigned to fire scars using visual cross-dating techniques or COFECHA. Fire frequency was compared between nine warm and nine cool plots, using the Weibull median fire interval. Fire intervals are expected to be shorter for warm aspect plots than cool aspect plots. We also compared the years since last fire to the Weibull median fire interval as one indicator of the current fire regime departure from historical conditions."

Daniels, L.D., J. Cochrane, and R.W. Gray. 2006. Refining mixed-severity fire regimes in the Rocky Mountain Forest District. Prepared for Tembec Inc., Cranbrook, B.C.; Can. For. Products Ltd., Radium Hot Springs, B.C.; and For. Investment Account, Victoria, B.C.

www.trench-er.com/public/library/files/mixed-severity-fire-regimes.pdf

"We have used tree rings to reconstruct the fire history of 10 stands dominated by large-diameter western larch, Douglas-fir, and ponderosa pine trees. All study sites were in the Montane Spruce (MS) and Interior Cedar Hemlock (ICH) biogeoclimatic zones in the Rocky Mountain Forest District. Each stand was structurally complex with an upper stratum of veteran trees that were >200 years old.

We developed 13 new site-specific ring-width chronologies, six for Douglas-fir, five for western larch and two for ponderosa pine and one regional chronology for each species. These chronologies were used to visually and statistically crossdate disks with fire scars to ensure fire scar dates were accurate at an annual level of resolution. The Douglas-fir, western larch and ponderosa pine chronologies were up to 323, 355 and 515 years in length, respectively. All chronologies had significant inter-annual variation and were significantly correlated over the period from 1750–2004, indicating the common influence of regional climate.

The 77 fire scar samples from nine of the 10 study sites yielded 204 fire scars and 70 unique fire dates from 1567 to 1944. Scars were recorded at only one site for 59 of 70 fire years. Notable years in the fire record occurred in years when a large number or percent of trees were scarred and fires scarred trees at more than one site. The highest scar frequencies were in 1720 and 1889, when 60% and 28% of recorder trees were scarred at three different sites. Regional fires, fires that caused scars at two or more sites, burned in 12 years from 1652 to 1922.

For individual sites, the fire scar records ranged from 177 to 470 years and included 13 to 37 fire scars, which represented four to 14 fire intervals. The Weibull median probability intervals (WMPI) ranged from 13.8 to 32.4 years and two to 102 years separated successive fires at each site. The current fire-free intervals ranged from 61 to 121 years and generally exceed the historic range of variation for the study stands, indicating a change to the fire regime during the past century. At the regional scale, only two fires scarred trees during the 65 years from 1940 and 2004. Over the last three centuries, the highest fire frequencies and shortest intervals between fires were during the settlement era from 1870 to 1939. Prior to the 1870, mean fire intervals significantly longer than fire intervals during the settlement era, likely reflecting the influence of land use and climate variation on fire frequency.

To extrapolate results from individual stands to the surrounding landscape requires knowledge of the abundance and distribution of the forest types in which we find evidence of mixed-severity fires. Our GIS determined that structurally complex forests currently represent c. 10% of forest in the ICH and MS zones of the Invermere and Cranbrook TSAs. These results provide important background information to facilitate a statistically robust regional analysis of fire history at the landscape scale.”

Daniels, L.D., J. Cochrane, and R.W. Gray. 2007. Fire history of the southern Rocky Mountain Trench: 1540–2005. In: Ecological restoration in southeastern British Columbia—grasslands to mountaintops. Oct. 12–13, 2007, Cranbrook, B.C. Columbia Mountains Inst. Appl. Ecol. and B.C. Chapter Soc. Ecol. Restoration, pp. 34–37.
www.cmiae.org/_PDF/Ecosystem_restoration_2007_conf_summary.pdf

“We used tree rings to reconstruct fire history and quantify the climate conditions associated with historic fires in the montane forests of the Rocky Mountain Forest District. The 10 study stands were dominated by large diameter western larch, Douglas-fir, and ponderosa pine trees, and were in the Montane Spruce (MS) Biogeoclimatic Zone. Each stand was structurally complex with an upper stratum of veteran trees that established prior to 1870.

Fire scar records from 10 old-growth sites were based on 100 fire scar samples that yielded 296 fire scars and 100 individual fire years between 1540 and 1944. At the site level, the median fire intervals ranged from 10.3 to 25.6 years, with 2 to 123 years separating successive fires within sites. Our reconstructions indicate historic fires formed a 'mixed severity' regime that included both frequent, low-severity fires and infrequent, high-severity fires. Although frequent, the impacts of these fires were relatively low. Many large trees survived, although some were damaged and formed fire scars. The greatest negative impacts were to understorey vegetation such as herbs, shrubs, seedlings, and saplings. In essence, these low-severity fires created and maintained old-growth forests and unique wildlife habitats. High-severity fires that initiated a new generation of forest also burned in the East Kootenays, but they burned less frequently, with intervals of 150 years or more between fires."

"In large part, the decrease in fire frequency and increase in intervals between fires are caused by human actions. Fire frequency began to decrease in the early twentieth century due to human land-use change. Agriculture and ranching changed the distribution of forests and fuels, decreasing the spread of fires and the occurrence of fire scars. In the past 60 years, fires were essentially eliminated from many forests due to very effective fire suppression—leading to the 'fire-suppression paradox.' By trying to protect our forests and communities from fire, we have made many dry forests of the East Kootenays more susceptible to severe fires. In the absence of the low severity fires, tree density and fuels can build up, increasing the chance of a severe, stand-replacing fire that is difficult to control and may threaten human communities."

Daniels, L.D., J. Cochrane, and R.W. Gray. 2007. Historical fire regime of the East Kootenays: 1540 to 2005. Univ. British Columbia, Dep. Geog., Vancouver, B.C.

www.for.gov.bc.ca/hfd/library/FIA/2007/FSP_Y071167b.pdf

"We have reconstructed fire history from 1540 to 2005 using tree ring records and fire scarred trees from 30 mid-elevation or montane forests of the East Kootenay region. Our reconstructions indicate historic fires formed a 'mixed-severity' regime that included both frequent, low-severity fires and infrequent, high-severity fires. Fire scars show that low-severity fires burned every 40 years, on average. The interval between fires varied from only 2 years to 100 years in individual patches of forest. Although frequent, the impacts of these fires were relatively low. Many large trees survived, although some were damaged and formed fire scars. The aboveground parts of most understory plants are killed by these fires, but they simply re-sprout and benefit from the release of nutrients into the soil. The greatest negative impacts were to seedlings and saplings. High-severity fires that initiated a new generation of forest also burned in the East Kootenays, but they burned less frequently, with intervals of 150 years or more between fires.

The fire regime changed abruptly during the 20th century. Over 400 years between 1540 and 1940, fires burned and scarred trees somewhere in the East Kootenay forests once every three years. Given this historical frequency, we would expect about 20 fire years since the 1940s, but our fire scar records included only 6 fire years! The low incidence of fires since the 1940s is partly due to variations in climate, but largely explained by cessation of burning by First Nations and very effective fire suppression."

Daniels, L.D., J. Cochrane, and R.W. Gray. 2007. Mixed-severity fire regimes: regional analysis of the impacts of climate on fire frequency in the Rocky Mountain Forest District. Prepared for Tembec Inc., Cranbrook, B.C.; Can. For. Products Ltd., Radium Hot Springs, B.C.; and For. Investment Account B.C., Victoria, B.C.
http://trench-er.com/public/library/files/mixed-severity-fire-climate-frequency.pdf

"We used tree rings to reconstruct the fire history and quantify the climate conditions associated with historic fires in the montane forests of the Rocky Mountain Forest District. All study stands were dominated by large-diameter western larch, Douglas-fir, and ponderosa pine trees and were in the Montane Spruce (MS) biogeoclimatic zone. Each stand was structurally complex with an upper stratum of veteran trees that established prior to 1870.

We developed 18 new site-specific ring-width chronologies, seven Douglas-fir, seven western larch and four ponderosa pine, and one regional chronology for each species. The Douglas-fir, western larch and ponderosa pine chronologies were up to 334, 506 and 516 years in length, respectively. All chronologies had significant inter-annual variation with narrow marker rings resulting from one- and two-year droughts driven by the combined effects of above-average temperatures and below-average precipitation.

Of the 30 fire history study sites, 10 sites were subjectively selected to represent old-growth stands and 20 sites were randomly selected to represent southerly, warm-aspect slopes (n = 10) and northerly, cool-aspect slopes (n = 10) in the landscape. Fire records from the 10 old-growth sites were based on 100 fire scar samples that yielded 296 fire scars and 100 individual fire years between 1540 and 1973. At the site level, the median fire intervals ranged from 10.3 to 25.6 years, with two to 123 years separating successive fires within sites. Results for the 20 randomly selected sites revealed longer median fire return intervals. Fire scars were present at 18 sites and 149 fire scar samples yielded 272 fire scars between 1509 and 2003. Median fire return intervals ranged from 15.5 to 77.5 years at the site level, with 5 to 138 years between fires within sites. For 60 of 76 fire years, scars were recorded at only one site; in seven years three or more sites burned. Evidently, the old-growth sites represent a subset of the landscape in which historic fire frequency was relatively high. We recommend that management decisions based on fire regime attributes take into account the full range of natural variation.

Historic fires burned during significant droughts and were most common during multidecadal periods of warm and dry climate driven by changes in the circulation patterns in the Pacific and Atlantic Oceans. Historically, fires burned during all combinations of climate conditions, but were more likely to burn when (a) the Pacific Decadal Oscillation (PDO) was positive and the Atlantic Multi-decadal Oscillation (AMO) was negative, regardless of variation in El Niño–Southern Oscillation (ENSO or El Niño *versus* La Niña events), (b) during El Niños when PDO and AMO were positive, and (c) during La Niñas, when PDO and AMO were negative. Fires were least likely when

PDO is negative and AMO is positive. Currently, we are in the positive phases of the PDO and AMO, meaning fires are most likely to occur during El Niño events.

Our fire scar records included only 6 fires since 1944. The low incidence of fire during the past 65 years suggests fire suppression is having a substantial impact on the fire regime of forests in the Rocky Mountain Forest District. Time since last fire has exceeded the maximum interval between historic fires at 16 of 28 (57%) sites. Had fires burned and scarred trees as frequently throughout the 20th century as they did over the entire fire record, we would have expected 20 fire years between 1944 and 2004. The low incidence of fire scars is partly due to climate and largely due to fire suppression. Climate conditions were not conducive to fire from 1946 to 1966, but conditions suitable for local and regional fires have dominated since 1981."

Daniels, L., J. Cochrane, R.W. Gray, and R. Kubian. 2009. Fire history of montane forests of the East Kootenays. Univ. British Columbia, Dep. Geog., Vancouver, B.C.

"We used tree rings to reconstruct the fire history and quantify the climate conditions associated with historic fires in the montane forests of the southern Rocky Mountain Trench, including Kootenay National Park. Our work focuses on components of the landscape where historically a mixed-severity fire regime was dominant. All study stands included large-diameter western larch, Douglas-fir, or ponderosa pine trees and were in the Montane Spruce biogeoclimatic zone. Each stand was structurally complex with an upper stratum of veteran trees that established prior to 1870. Our goal is to provide baseline data on fire frequency that can be used to guide ecologically-based restoration of the historic fire regime and fuels mitigation.

Of the 30 fire history study sites, 10 sites were subjectively selected to represent old-growth forests and 20 sites were randomly selected to represent southerly, warm-aspect slopes (n = 10) and northerly, cool-aspect slopes (n = 10) in the landscape. Fire records were based on 249 fire scar samples that yielded 567 fire scars between 1509 and 2003. At the old-growth sites, the median fire intervals ranged from 10.3 to 25.6 years, with two to 123 years separating successive fires within sites. At the remaining sites, median fire return intervals ranged from 15.5 to 77.5 years, with 5 to 138 years between fires within sites. Evidently, the old-growth sites represent a subset of the landscape in which historic fire frequency was relatively high.

Our fire scar records included only 6 fires since 1944. Time since last fire has exceeded the maximum interval between historic fires at 16 of 28 (57%) sites. Had fires burned and scarred trees as frequently throughout the 20th century as they did over the entire fire record, we would have expected 20 fire years between 1944 and 2004. The low incidence of fire scars is partly due to climate and largely due to fire suppression. Climate conditions were not conducive to fire from 1946 to 1966, but conditions suitable for fires have dominated since 1981. The low incidence of fire during the past 65 years suggests fire suppression is having a substantial impact on the fire regime of forests in the southern Rocky Mountain Trench.

We have two recommendations for managers:

1. Management decisions based on fire regime attributes must account for the full range of natural variation. In many montane forests, low to moderate severity fires burned on average every 15 to 75 years (range = 5 to 138 between fires).
2. Long fire free intervals during the 20th century are the result of climate variation and fire suppression. Where fire suppression has altered the fire regime, fuels likely have accumulated and may result in severe fires. Ongoing research in Kootenay National Park is designed to test for the impacts of fire suppression on forest composition, structure and fuels."

Daniels, L.D., J. Cochrane, R.W. Gray, N. Soverel, M. Welton, S. Tiffany, V. Uppal, and N. Theroux. 2009. Fire history in the East Kootenays and impacts on forest dynamics. Univ. British Columbia, Dep. Geog., Vancouver, B.C. Tech. Rep. (part 1).
www.for.gov.bc.ca/hfd/library/FIA/2009/FSP_Y093167a.pdf

"This report includes data from 10 study plots, nine of which are located in the western part of Kootenay National Park and one plot (Plot 18) is located near Cranbrook. Cambial scars and disturbance history were reconstructed for Plots 11, 23, 24, 25, 26, 27, 28, 31 and 32. Stand composition, structure and dynamics was reconstructed for Plots 11, 23, 26, 27, and 29. Various aspects of regeneration dynamics was explored using seedlings and saplings from Plots 11, 18, 23, 26, 27, 28 and 29."

"For the nine plots combined, we successfully crossdated cambial scars on 54 disks, including 36 lodgepole pine, 14 Douglas-fir, two hybrid spruce and two decayed disks for which species could not be determined. Of 76 scars, 41 were caused by fire which burned in 14 different years between 1718 and 1959. Fire years were: 1718, 1774, 1817, 1818, 1841, 1865, 1869, 1880, 1883, 1887, 1894, 1917, 1929 and 1959. Two plots included fire scars in 1841 and 1887. Consistent with Master's (1989, 1990) assessment of fire history, the most widespread fire that we documented was in 1917, which scarred trees in six plots. The many scars on lodgepole pine during the 20th century were not caused by fire, but the causal agent remains undetermined."

Daniels, L.D., Z. Gedalof, M.F.J. Pisaric, C.J.C. Mustaphi, E. Da Silva, H. Marcoux, V. Mather, J. Nesbitt, E. Paul-Limoges, J. Perrault, and C. Steele. 2011. Historic climate-fire-vegetation interactions of the West *versus* East Kootenays: implications of climate change and fire suppression. Prepared for Univ. British Columbia, Dep. Geog., Vancouver, B.C.; Carleton Univ., Dep. Geog., Ottawa, Ont.; and Univ. Guelph, Dep. Geog., Guelph, Ont.
www.trench-er.com/public/library/files/kootenay-fire-report.pdf

"In western North America, wildfire is a primary disturbance driving the diversity, age structure, and dynamics of forest. In some forests, climatic warming combined with fire exclusion has created conditions conducive to catastrophic wildfires. Understanding the relationships between wildfire and environmental change is a fundamental concern, particularly in forests near the wildland-urban interface where human lives and property are at risk. In this project, we compared the fire history and forest dynamics of the Joseph-

Gold Creek watersheds near Cranbrook in the East Kootenay district and remnant old forests surrounding Nelson in the West Kootenay district of southeastern British Columbia.

We used multiple lines of evidence, including charcoal in lake sediments and analysis of tree rings, to reconstruct historic fire regimes. In both the West and East Kootenay study areas, fire regimes varied significantly with steep elevational gradients. At high elevations, stand-replacing fires burned every 150-300 years according to our lake sediment, fire scar and forest age results. The lake sediment research yielded a 10,000-year fire reconstruction for high elevations (>2000 m.a.s.l.) in the West Kootenay study area. It included 36 fires, burning once every 270 years on average. Fire frequencies peaked 4,000-6,000 years ago, but 2-3 large fires burned during the past 1,000 years. There was at least one large fire in the early 1900s. Forest history reconstructions from tree rings corroborated this evidence. In the West Kootenay study area, high elevations forests established after severe fires that burned up to 340 years ago but many forests established from 1850 to the 1890s, concurrent with the gold rush and European settlement. In the East Kootenay study area, severe fires burned 100-360 years ago. A widespread fire in 1910 affected the forests at all elevations, scarring many trees, and killing even fire-resistant tree species.

In the low-elevation forests, below 1350 m.a.s.l. in the West and 1550 m.a.s.l. in the East Kootenays, there was abundant evidence of frequent, low-severity fires that burned and scarred trees once every 25 to 50 years, on average. Fires burned in late summer of drought years, often during the warm phase of the Pacific Decadal Oscillation, a climate cycle causing warm, dry conditions in the Kootenay region. Despite the historic frequency of fires and recent periods of suitable climate, these forests last burned 56 to 159 years ago. The unusually long fire-free periods are evidence of the strong effects of fire exclusion and suppression during the 20th century. The lack of recent fires was reflected in the composition of low-elevation forests in both study areas. The forest canopies were dominated by thick-barked, fire-tolerant species but subcanopy trees were shade-tolerant, thin-barked species that are susceptible to fire. Although small, the subcanopy trees were the same age as the canopy trees; they established after the last fire and did not represent continuous in-filling of the forest. Historically, the low-severity fires would have killed the smaller thin-barked trees and consumed fine fuels such as needles and branches on the ground. In absence of low-severity fires, dense forests have been perpetuated and ground fuels have accumulated. Paradoxically, by protecting the forests from low-severity fires, we have likely increased the risk of severe wildfires in the low-elevation forests surrounding Cranbrook and Nelson."

Da Silva, E. 2009. Wildfire history and its relationship with top-down and bottom-up controls in the Joseph and Gold Creek watersheds, Kootenay Mountains, British Columbia. MSc thesis. Univ. Guelph, Guelph, Ont. http://trench-er.com/public/library/files/wildfire-history-joseph-gold-creeks.pdf

"This study identifies patterns of historic fire activity that characterise the Joseph and Gold Creek watersheds near Cranbrook, British Columbia as a mixed-severity regime and provide evidence that both bottom-up and top-down controls significantly regulate fire activity. Fire scar chronologies from 33 plots in the watersheds demonstrate that the relative importance of bottom-up controls vary over very short distances. Fire frequency was significantly higher in plots found on a steep southwest-facing sloping compared with the rest of the landscape, an area characterised by xeric conditions. Species distribution was strongly driven by elevation related microclimate and transitioned from fire-resistant to sub-alpine species along elevation gradients, likely reflecting a transition in fire activity – although this could not be substantiated by the fire scar record because of a lack of fire history information. Historic fire activity in this area showed a strong relationship with drought, which may be associated with the warm phase of the Pacific Decadal Oscillation. Similar results were found when analyses were completed using regionally significant fire years. The effects of fire exclusion in the past half century are evident in this fire history reconstruction. The low incidence of fire in the hundred years following a large event in the early 20th century has served to homogenize the landscape and increase fire hazard in the wildland-urban interface."

Dawson, R. 1997. Natural disturbance patterns in the Cariboo Forest Region–summary of results. For. Renewal BC, Res. Program. B.C. Min. For., Cariboo For. Region, Williams Lake, B.C.
www.for.gov.bc.ca/hfd/library/frbc1997/frbc1997mr158.pdf

"The study area sampled in year one of this project included twenty-three 1:20,000 forest cover maps sheets covering an area of approximately 3400 km^2. The study area is located west of the Fraser River on the Chilcotin plateau south of the Itcha Mountain Range. It includes 1520 km^2 in the SBPSxc, 1855 km^2 in the MSxv, 18 km^2 in the ESSFxv and 6 km^2 in SBPSdc and includes most of the area within three draft landscape units. This area is representative of the cold dry climatic conditions found on much of the Chilcotin Plateau."

"A very simplistic analysis of the data indicates that approximately 75% of the area of forested land is under 140 years of age and that over one half of the area is made up of age class patches greater than 1000 ha in size. Although detailed interpretations will have to consider a number of important factors which influence this data, this simplified analysis portraying a disturbance regime characterized by frequent, large fires corresponds to that hypothesized by local ecologists. Two important factors which will have to be considered in further interpretations include the effects of fire suppression over past 40 years and the fact that the forest cover data information used to generate this analysis was not designed to provide accurate estimations of seral age, especially for the older age classes.

The size, frequency and arrangement of forest remnants (older forest patches within a matrix of younger forests) is an interesting result of the natural disturbance history and an important aspect of the landscape pattern from an ecological viewpoint. These remnant patches are thought to play an important ecological role by acting as refugia and 'infection' sources for organisms to recolonize the surrounding disturbed area. They also provide horizontal habitat diversity and provide islands of habitat which may serve as 'stepping stones' for animal movements. In the study area, remnants covered 5.5% of the total forested area and averaged approximately 13 ha in size with much variation around the mean. We have to be aware that many smaller remnants may be below the size resolution provided by the forest inventory database and would therefore be missed by this analysis."

"The data show that 46% of the total study area is composed of forests greater than 100 years of age and that the mature/old component is predominantly in large patches with a high proportion of interior forest. Seventy-eight percent (35/45 as a percent) of this mature and old forest is in patches over 1000 ha in size. Sixty-nine percent (31/46 as a percent) of this mature/old forest is 'interior forest'" buffered from the forest edge.

Gray, R.W., B. Andrew, B.A. Blackwell, A. Needoba, and F. Steele. 2002. The effect of physiography and topography on fire regimes and forest communities. Prepared for Habitat Conservation Trust Fund, Victoria, B.C. www.for.gov.bc.ca/hfd/library/FIA/2002/FIA2002MR009.pdf

"The historic fire regimes found in south aspect NDT3 and NDT4 polygons sampled in 5 forest districts (Invermere [IDFdm2, MSdm1], Cranbrook [IDFdm2, MSdk], Kamloops [IDFdk1, IDFxh2, MSxk1], Lillooet [PPxh2, IDFdk1], and Squamish [IDFww, ESSFmw]) were characterized by high fire frequency with narrow variability around the mean, and variable intensity. Mean fire intervals (MFI) recorded for the 5 sites ranges from a low of 6.5 for Lillooet and a high of 17.9 for Invermere. The MFI's recorded are some of the lowest numbers recorded in the province.

The results of the analysis on south aspects suggest frequent, mixed-severity fire regimes have influenced historic stand structure and ecosystem processes in biogeoclimatic subzones and variants currently considered to have experienced infrequent stand-replacement fire regimes. This is true for the MSdk in Cranbrook, MSdm1 in Invermere, MSxk in Kamloops and Lillooet, and the ESSFmw in Squamish. Additionally, significant issues exist in some Forest Districts concerning inaccuracies in the current mapped distributions of biogeoclimatic units. These identified discrepancies can have significant consequences where the conservation of biodiversity is concerned. The current designation of many of these biogeoclimatic units as Natural Disturbance Type 3 warrants further investigation. Fires appear to be of more mixed-severity as opposed to infrequent, high-severity."

Gray, R.W. and L.D. Daniels. 2007. An investigation of fire history in the lower Gold/Joseph Creek watershed. Prepared for City of Cranbrook, Cranbrook, B.C.
www.trench-er.com/public/library/files/joseph-creek-fire-history.pdf

"At Joseph Creek West [MS], the interval for fire analysis was from 1449 through 2006. We crossdated 32 fire scars, with one to six fire scars per tree. We identified 18 fire years between 1540 and 1910. Fire years in which multiple trees scarred were 1677, 1701, 1721, 1831, 1869, 1905 and 1910. The Weibull median interval between fires was 17.2 years. The minimum interval between successive fire scars was three years from 1698 to 1701. The maximum interval between fires was the 93 years from 1540 to 1633, which is also the first pair of fire scars in the record. It is possible that fires burned during the period between 1540 and 1633 but subsequent fires may have burned off scar evidence or scarred trees may have decayed. The last fire scar was formed in 1910; so it has been 97 years since the last fire. The 1910 fire scarred three of six trees that were living at that time."

"The fire scar record provides clear evidence that historically, low- to moderate-severity fires frequently burned the Joseph Creek West site. Several western larch were scarred five or six times but not killed by fire. Each of the five lodgepole pine sampled had at least one scar, with two samples containing two scars. All lodgepole pine were scarred when they were <40 years old. Two lines of evidence suggest that fires in the mid-19th century were of moderate- to high-severity that killed overstory larch and provided the opportunity for a cohort of lodgepole pine to establish. First, outermost ring dates of five western larch snags indicate they died c. 1838 to 1878. Second, the sampled lodgepole pine had pith dates of 1873 to 1883, with wide rings closest to the pith indicating fast initial growth, likely in a relatively large opening. These pith dates were for samples that were cut about 30 cm above the ground, therefore, tree germination dates were likely five to ten years earlier than the pith dates."

Hallett, D.J. and L.V. Hills. 2006. Holocene vegetation dynamics, fire history, lake level and climate change in the Kootenay Valley, southeastern British Columbia, Canada. J. Paleolimnol. 35(2):351–371. www.springerlink.com/content/f0hk954w50534203/

"The environmental history of the Kootenay Valley in the southern Canadian Rockies was reconstructed using lake sediment from Dog Lake, British Columbia, and compared to other paleoenvironmental studies in the region to understand how vegetation dynamics and fire regimes responded to climate change during the Holocene. A pollen-based vegetation reconstruction indicates five periods of vegetation change. At 10,300 cal yr B.P. *Pinus–Juniperus* parkland colonized the valley and by 7600 cal yr B.P. was replaced by mixed stands of *Pinus*, *Picea* and *Pseudotsuga/Larix*. Fire frequencies increased to their Holocene maximums during the 8200–4000 cal yr B.P. period. From 5500–4500 cal yr B.P. *Pseudotsuga/Larix* reached its maximum extent in the Kootenay Valley under a more frequent fire regime. At 5000 cal yr B.P. *Picea* and *Abies* began to expand in the area and by 4500 cal yr B.P. the forest shifted to a closed montane spruce forest type with dramatically reduced fire frequency. The shift to less frequent forest fires after 4500 cal yr B.P., along with a moister *Picea* – dominated closed forest, corresponds to Neoglacial advances in the Canadian Rockies and Coast Mountains. Fire intervals after 4000 cal yr B.P. are significantly longer than the shorter fire intervals of the early to mid Holocene. A return to drier, more open forest condition occurs between 2400–1200 cal yr B.P. with a slight increase in fire activity and summer drought events. Lower lake levels inferred by charophyte accumulation rates during the 2400–1200 cal yr B.P. interval support this moisture regime shift. An abrupt shift to *Picea* dominated forest occurred from 1200–1000 cal yr B.P. and a final period of wet–closed forest cover reaches its maximum extent from 700–150 cal yr B.P. that appears to be a response to Little Ice Age cooling. Present forests are within their natural range of variability but are predicted to shift again to a drier more open structure with increased *Pseudotsuga/Larix* cover. More frequent stand replacing fires and increased area burned likely will accompany this change due to continued global warming."

Hallett, D.J., R.W. Mathewes, and R.C. Walker. 2003. A 1000-year record of forest fire, drought and lake-level change in southeastern British Columbia, Canada. The Holocene 13(5):751–761.
http://hol.sagepub.com/cgi/content/abstract/13/5/751

"High-resolution charcoal analysis of lake sediments and stand-age information were used to reconstruct a 1000-year fire history around Dog Lake, which is located in the montane spruce zone of southeastern British Columbia. Macroscopic charcoal (>125 μm) accumulation rates (CHAR) from lake sediment were compared with a modern stand-origin map and fire-scar dates in the Kootenay Valley to determine the relative area and proximity of fires recorded as CHAR peaks. Small fires close to the lake and larger more distant fires appear as similar-sized peaks in the record. This information reinforces previous findings where CHAR peaks represent a complex spatial aggregation of local to extra-local fires around a lake site. CHAR peaks indicate frequent stand-destroying fires during the 'Mediaeval Warm Period' (~AD 1000–1300), and other significant fires at *c.* 1360, 1500, 1610 and 1800. We also present a proxy measure of lake-level changes based on a comparison of accumulation rates of *Chara globularis*-type oospores over the last millennium and the present distribution of charophytes in the lake basin. Lower water levels, represented by few or no *Chara* oospores, correspond to times of regional drought and large forest fires around the lake. Higher lake levels, represented by increased *Chara* oospore accumulation rates, correspond to wetter climate periods during the Oort, Wolf, Sporer and Maunder solar sunspot minima, when little or no fire activity occurs around the lake."

Hallett, D.J. and R.C. Walker. 2000. Paleoecology and its application to fire and vegetation management in Kootenay National Park, British Columbia. J. Paleolimnol. 24(4):401–414.
www.springerlink.com/content/xx682280210226g0/

"High-resolution analysis of macroscopic charcoal and pollen ratios were used to reconstruct a 10,000 yr history of fire and vegetation change around Dog Lake, now in the Montane Spruce biogeoclimatic zone of southeastern British Columbia. Lake sediment charcoal records suggest that fire was more frequent in the early Holocene from 10,000 to 8200 calendar yrs BP, when climate was warmer and drier than today and forest fuels were limited. Fire frequency increased and reached its maximum during the early to mid-Holocene from 8200 to 4000 calendar yrs BP, corresponding to the dry and warm Hypsithermal period in the Rocky Mountains. During the Hypsithermal period forests around Dog Lake were dominated by *Pseudotsuga/Larix*, *Pinus* and open meadows of Poaceae that were subject to frequent fire. From 4000 calendar yrs BP to present, fires became less frequent with the onset of cooler and wetter Neoglacial climate and an increase in wet–closed *Picea* and *Abies* forests in the valley. Changes in fire frequency are supported by dry–open/wet–closed pollen ratio data indicating that forest type and disturbance regimes vary with changing climate. The fire frequency and forest cover reconstructions from Dog Lake are a first attempt at defining a range of natural variability for Montane Spruce forests in southeastern British Columbia. Fire and vegetation management in Kootenay National Park can now use this century to millennial-scale range of variability to define the context of current forest conditions and potential changes under global warming scenarios."

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.L. Harper, and B.M. Wikeem. 1991. Montane spruce zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 183–194.
www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap12.pdf

"One of the most distinctive features of the MS landscape is the extensive, young and maturing seral stands of lodgepole pine that have formed following wildfire. In wetter subzones, and on wet sites in all areas, maturing seral stands contain mixtures of lodgepole pine, hybrid white spruce, and subalpine fir. Hybrid white spruce and subalpine fir are the dominant, shade-tolerant, climax trees; however, lodgepole pine's frost tolerance, resistance to drought, and serotinous cones all favour its establishment after fire. Under the lodgepole pine canopy, frost and surface drying are reduced, and hybrid white spruce and subalpine fir can regenerate.

Douglas-fir is an important seral species in zonal ecosystems, and is a climax species on warm, south-facing slopes in the driest ecosystems. Western larch is confined to the eastern part of the zone, where it frequently occurs as a seral species after fire."

Lloyd, D., K. Angove, G. Hope, and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 23.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh23.htm

The MSxk "occurs at mid-elevations in the central part of the Thompson Plateau, from the U.S. border to the Bonaparte Plateau, and in the Clear and Camelsfoot ranges on the Fraser Plateau." "A history of wildfires has resulted in mature seral Pl [lodgepole pine] stands dominating the landscape of this subzone. Climax stands of Sxw [hybrid white spruce] and Bl [subalpine fir] rarely occur."

Meyn, A. 2002. Fire history of forest remnants left by fire in *Pinus contorta* Dougl. ex Loud. dominated forests in the Montane Spruce zone of southern British Columbia, Canada. M. thesis. Geo-ecol., Univ. Bayreuth, Bayreuth, Germany.
www.for.gov.bc.ca/HFD/library/documents/Meyn_2002.pdf

"Fire is one of the major natural disturbance agents in forests dominated by *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm. (hereafter referred to as *Pinus contorta*) in western North America. Since forest fires rarely kill all forest vegetation within their perimeter, burned landscapes typically represent a mosaic of burned and unburned patches.

Goal of this study was to determine the longest naturally fire free interval of remnants left by fire in *Pinus contorta* dominated forests in British Columbia (Canada). In order to increase the chance of finding long fire free intervals, study areas situated at the wetter end of the ecological amplitude of this forest type were chosen for investigation. These are located in the Montane Spruce biogeoclimatic zone of southern Interior British Columbia.

Tree ages, the absence of fire scars and evidence of succession indicated that the remnants had stayed fire free since their stand initiation. Based on these results the fire free interval was estimated to be 129 years for three of the selected remnants, respectively 234 years and 309 years for the other two remnants. Although these are conservative estimates, it is unlikely that fire free intervals are underestimated by more than 10–20 years, because they are based on postfire cohort age. And it is unlikely that the length of the fire free intervals was influenced by fire suppression.

The longest fire free interval found for a remnant at the wetter end of the ecological amplitude of *Pinus contorta* dominated forests in this study (309 years), is nearly twice as long as the longest fire free interval found for a remnant in *Pinus contorta* dominated forests at the drier end of their ecological amplitude (165 years;...).

Results of this study indicate that forest islands left in clear cuts to imitate remnants left by fire, should have a rotation age up to 309 years in the MSdm1. During this time they should be excluded from any kind of harvesting and other management practices in order to allow the succession found in two of the investigated remnants to take place."

Meyn, A. and M.C. Feller. 2006. Fire history of forest remnants in wetter lodgepole pine dominated forests in southern British Columbia, Canada. N.W. Sci. 80(2):86–94.
www.vetmed.wsu.edu/org_nws/NWSci%20journal%20articles/2006%20files/Issue%202/02%20Meyn%20and%20Feller.pdf

"Forest fires in British Columbia often leave patches of unburned vegetation (forest remnants) within their perimeters. These remnants help to maintain biological diversity and structural complexity in stands. To be able to maintain patterns similar to those created by fire, we need an understanding of the fire history of these forest remnants. We investigated the history of forest remnants in two study areas located in wetter lodgepole pine dominated forests in two Montane Spruce biogeoclimatic subzones in southern central British Columbia. The objectives of the study were to determine if there were any remnants that had never burned and, if not, what were the longest fire-free intervals within them. Aerial photographs, forest cover maps, and ground searching were used to investigate a total of 14% (47,000 ha) of one subzone and 17% (17,000 ha) of the other. This yielded 12 remnants in which plots were established to determine recent fire history. All twelve remnants had burned at some time. Stand history reconstruction, including dendrochronological analysis, of five of these remnants suggested that they had been formed from 3 different fires. The longest fire-free intervals within the remnants were estimated to range from 129 to 309 years. This is up to nearly twice as long as the longest fire-free intervals found for remnants in drier lodgepole pine forests in British Columbia."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 1. Very dry climatic region. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

In the MSc [MSxk], in the eastern part of the study area, "past wildfires have had a pronounced effect on the existing forest and understory floristic composition. Crown fires were common and now extensive areas are primarily even-aged stands of young and maturing Pl [lodgepole pine]."

Mitchell, W.R., R.E. Green, D. Lloyd, F. Russell, W. Erickson, and D. Walkem. 1981. Identification and interpretation of ecosystems of the western Kamloops Forest Region—first approximation. Volume 2. Dry and subcontinental climatic regions. B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Handb. 2. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh02.htm

In the MSb [MSdm], in the western and northeastern parts of the study area, "past wildfires have had a pronounced effect on the existing forest and understory floristic composition. Crown fires were common and now extensive areas are primarily even-aged stands of young and maturing Pl [lodgepole pine]."

Morrison, J. and R. Gray. 2005. Indicators of indigenous fire management—learning from the trees themselves. Forestry Innovation Investment Ltd., Vancouver, B.C. and Forintek Can. Corporation, Vancouver, B.C. www.for.gov.bc.ca/hfd/library/FIA/2003/R2003-186a.pdf

"Paradise Lake yielded 5 fire-scar samples, all lodgepole pine, with fire dates from 1869 to 1908. This site exhibited a historically frequent and low-intensity fire regime prior to 1910.... Fires were very frequent (MFI = 13 years) [minimum 4, maximum 20 years] for a pure lodgepole pine forest type in the MSxk. With high fire frequency, fuel accumulations would be kept low in turn keeping fire intensity low. Further evidence of low fire intensity is the initial scarring, and in 1 case re-scarring, of lodgepole pine which is not considered to be highly fire-tolerant.... The historic fire regime at Paradise Lake resulted in a mixed age-cohort stand with lodgepole pine germination not highly correlated with fire activity.

A total of 6 fire-scar samples were collected from Paradise Lake East, all again being lodgepole pine. The earliest fire was recorded in 1796 and the latest in 1886. The historic fire regime found at Paradise Lake East is significantly different from the Paradise Lakes site. Mean fire frequency is longer at 22.5 years [minimum 2, maximum 43 years] versus 13 years, and intensity appears to be higher with more trees scarred per fire event.

The result of these fire regime characteristics appears to be a temporally mixed-severity fire regime where fires were less frequent, permitting higher accumulations of between fire fuels to build up, resulting in higher fire intensity and severity with the subsequent fire. The stand structure under this regime exhibits more of an even-aged characteristic than uneven-aged.

Seven lodgepole pine fire-scar samples were collected from Island Lake with the earliest fire in 1751 and the latest in 1869. This site is very similar to the Paradise Lake East site in historic fire regime frequency [MFI = 25, minimum 3, maximum 64 years] and intensity and resultant stand structure."

Nesbitt, J.H. 2010. Quantifying forest fire variability using tree rings Nelson, British Columbia 1700–present. MSc thesis. Univ. British Columbia, Dep. Geog., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/28789
"This study uses dendroecology to provide direct evidence of historic forest fires and their effects on stand structure and dynamics at a local scale in the montane forests in southeastern British Columbia (BC). Using tree ages and fire-scarred trees, I determined the historic variability of fires by quantifying stand dynamics in relation to past fires in the mixed-conifer forests surrounding Nelson, a wildland-urban interface community in southeastern BC. I built fire records that extended from 1642–2009 across 18 sites in the ~160 000 hectare study area. Although a watershed-level fire signal is evident, site-to-site differences in fire-scar records and stand dynamics suggest that topography and land use caused variability in the fire histories of the individual sites. Numbers of fire-scarred trees and importance values of fire-tolerant trees decreased significantly with elevation. Fire-intolerant trees were most abundant in the subcanopy across all elevations. Most strikingly, no fires were recorded since 1932 across all sites, suggesting that fire exclusion has been effective and that future stands will likely continue to diverge from historic stands by becoming more dense, more homogenous in species composition, and, as a result, more susceptible to high-severity fires."

Parminter, J. 1987. Fire history and fire ecology of the Height-of-the-Rockies Wilderness Area. B.C. Min. For. Lands., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/pubs/docs/scv/SCV107.pdf
"In the MSa [MSdk] subzone the Palliser valley floor has burned, presumably as a result of fires which originated lower in the valley. As this subzone is the lowest of the three found within the area, the post-fire regeneration times here will be the shortest, probably on the order of 5 to 7 years. Over a long period the forests will lose their lodgepole pine and/or Douglas-fir components (without further fires) and the Engelmann spruce will dominate. Subalpine fir will dominate the lower canopy in older stands and could become a significant component after the Engelmann spruce starts to experience mortality."

Pollack, J., H. Quesnel, C. Hauk, and H. MacLean. 1997. A quantitative evaluation of natural age class distributions and stand replacement intervals in the Nelson Forest Region. Vol. 1. B.C. Min. For., Nelson For. Reg., Nelson, B.C. Tech. Rep. TR-015.
www.for.gov.bc.ca/hfd/pubs/RSI/FSP/Nelson/RNE_TR-015.htm
Using the corrected Forest Inventory Planning (FIP) age-class data, estimated stand replacement intervals were 107 years for the MSdm1 and 108 years for the MSdk.

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm
"Lodgepole pine forests dominate the MS landscape. Most stands have an even-aged, even-sized canopy, which originated following wildfire. Hybrid

white spruce is the principal tree species in the understory, followed by subalpine fir and lodgepole pine. In many stands, especially those less than 80–100 years old, tree regeneration is sparse. Due to the slow growth of spruce and subalpine fir under a pine canopy in these cold, dry climates, the lodgepole pine forests are long-persisting seral stages."

"The MSdc2 is a very small variant that occurs on leeward slopes of the Pacific Ranges and northwestern parts of the Chilcotin Range. Specifically it occurs in the valleys of Chilko and Tatlayoko lakes, Mosley Creek, and Klinaklini and Atnarko rivers." On zonal site series "the climax forest canopy is dominated by subalpine fir and hybrid white spruce but, due to a history of frequent wildfires, most stands are seral stages dominated by lodgepole pine and subalpine fir. A few Douglas-fir are often present. Tree regeneration is predominantly subalpine fir together with lesser numbers of hybrid white spruce."

"The MSdv is a very small subzone that occurs around Taseko Lakes and in the adjacent Lord River valley and Yohetta Valley. It extends from valley bottoms to the lower boundary of the ESSFxv." On zonal site series "the climax forest canopy is dominated by subalpine fir and hybrid white spruce but, due to frequent wildfires, most stands are seral stages dominated by lodgepole pine."

"The MSxv is a moderately large (8731 km^2) subzone that occurs primarily within the Cariboo Forest Region. It is most extensive on the plateau landscapes that rise gently towards the Itcha Mountains from the south, east, and north. It also common on the leeward slopes of the Coast Mountains, overlooking the Fraser Plateau, at elevations above the SBPS and below the ESSFxv. It extends for only a short distance from the plateau into the valleys of the Coast Mountains and does not occur east of the Fraser River." On zonal sites "due to frequent wildfires and slow rates of succession, natural stands are most often dominated by lodgepole pine less than 200 years old. Hybrid white spruce, lodgepole pine, and occasionally subalpine fir regeneration are present."

MOUNTAIN HEMLOCK BIOGEOCLIMATIC ZONE

Brink, V.C. 1959. A directional change in the subalpine forest–heath ecotone in Garibaldi Park, British Columbia. Ecology 40(1):10–16. http://dx.doi.org/10.2307/1929917

"Fire is rare in the Garibaldi Lake area. Very few old trees carry fire scars and in only one pit of dozens dug was charcoal found. Fuel values in the timberline area are generally low but are highest in the dense patriarchal groves on the low scattered ridges and tree 'islands.' If fire was an agent in the creation of subalpine heaths, why were the trees of high fuel value not burned? It is doubtful if aboriginal peoples would fire the meadows of the Black Tusk area for most of their food plants, such as the Indian potato (*Claytonia lanceolata*) are much more abundant to the eastward."

Brooke, R.C., E.B. Peterson, and V.J. Krajina. 1970. The subalpine mountain hemlock zone: subalpine vegetation in southwestern British Columbia, its climatic characteristics, soils, ecosystems and environmental relationships. Ecol. West. N. Am. 2(2):147–349.

"Fires may also have been significant in altering the vegetation pattern in the subalpine landscape although fire evidence on present tree trunks is largely absent except for isolated trees struck by lightning. Traces and fragments of charcoal were found in approximately one-third of the 140 soil pits studied. Although charcoal was more commonly found in soil pits within the Forest Subzone, it was also found in pits at elevations of 5600 ft [1700 m] where tree development at present is krummholz-like. Fragments of charcoal found below organic horizons or large charcoal fragments in the organic horizons were considered to be evidence of past fires *in situ*. A plot of decade of establishment of all tree species and for decade of establishment for trees now located in areas where charcoal was found in soil pits suggests that fires may have occurred in the late 1700's and early 1600's.... Large fragments of charcoal well into the mineral soil further suggest that the fires were severe and that the charcoal fragments represent tree roots. Nevertheless, specific dates for fires must be considered speculative as the absence of tree establishment in particular decades at high elevations may be due either to inadequacies in sampling or the occurrence of particularly unfavourable climatic periods of a short cyclical nature."

Brown, K.J. and R.J. Hebda. 2003. Coastal rainforest connections disclosed through a Late Quaternary vegetation, climate, and fire history investigation from the Mountain Hemlock Zone on southern Vancouver Island, British Columbia, Canada. Rev. Palaeobot. Palynol. 123(3-4):247–269. www.sciencedirect.com/science/article/pii/S0034666702001951

"The post-glacial vegetation and fire history of high-elevation regions on southern Vancouver Island is described using palynological and charcoal records from Porphyry and Walker lakes. A zone consisting mainly of *Artemisia*, Poaceae, and ferns occurs in the basal clay at Porphyry Lake and may represent a non-arboreal ecosystem in a late-Wisconsin glacial refugium. At both sites, a fire-free *Pinus contorta* zone occurs before ca 14 160 calendar years before present (cal BP). Climate at this time is interpreted as being cool to cold and dry. Mixed conifer forests of *Picea*, *Abies*, *Tsuga mertensiana* and *Pinus contorta* replaced the *Pinus contorta* woodlands after ca 14 160 cal BP. Fires are recorded for the first time. Climate is interpreted as cool and moist. Forests of *Abies*, *Picea*, *Tsuga heterophylla*, *Pseudotsuga menziesii*, and *Alnus* developed and expanded during the early-Holocene from ca 11 400–9910 to 7700–7300 cal BP as climate warmed and dried. Charcoal increased during this interval, indicating only slightly more fire activity and reflecting continued moist conditions at high elevations. In the mid-Holocene from ca 7700–7300 to 5200–4900 cal BP, *Tsuga heterophylla* pollen values increased as forests became dominated by *Tsuga heterophylla*, *Picea*, and *Abies* with *Alnus* in response to increased moisture. The increase in charcoal influx at this time may reflect an increase in slope wash and erosion resulting from a wetter climate rather than an increase in fire incidence. Starting at ca 5200–4900 cal BP, a further increase in *Tsuga heterophylla* combined with an increase in *Tsuga mertensiana* and Cupressaceae pollen suggest that the late-Holocene was characterised by increasing moisture and decreasing temperatures. Late-Holocene forests consisted predominately of *Tsuga heterophylla*, *Tsuga mertensiana*, Cupressaceae, and *Pinus contorta*. A slight reduction in charcoal influx at ca 4600 cal BP implies fewer fires. A recent increase in charcoal at Walker Lake at 1700 cal BP may reflect anthropogenic burning. The timing of events and response of taxa on southern Vancouver Island are comparable to other coastal sites in northwestern North America, suggesting that past ecosystems were widespread and contemporaneous. Palaeoecosystem changes detected in one region of the Pacific Northwest likely reflect a widespread response to climate throughout the ~2500 km long zone, a zone that today is home to half of the world's remaining coastal temperate rainforest."

Daniels, L.D. and R.W. Gray. 2006. Disturbance regimes in coastal British Columbia. BC J. Ecosystems Manag. 7(2):44–56.
http://jem.forrex.org/index.php/jem/article/view/542

"What is the dominant disturbance regime in coastal British Columbia? In this literature review, we discuss the relative importance of fire versus canopy gaps as agents of disturbance affecting the structure and dynamics of unmanaged coastal forests in British Columbia. Our analyses focus on the province's wet coastal temperate rain forests, specifically the Hypermaritime and Very Wet Maritime Coastal Western Hemlock (CWHvh and CWHvm) subzones, and the Wet Hypermaritime and Moist Maritime Mountain Hemlock (MHwh and MHmm) subzones. After reviewing the relationships between disturbance events, disturbance regimes, and stand dynamics, we critically assess the traditional classification of fire regimes in the wet coastal temperate rain forests, in part by differentiating between fire occurrence and mean return intervals. We provide four lines of evidence to reject the traditional view that stand-initiating fire at intervals of 250–350 years was the dominant disturbance regime in the wet coastal temperate rain forests of British Columbia. According to recent field research, historical fires were very infrequent in wet coastal temperate rain forests and were more likely low- and mixed-severity events, rather than stand-initiating fires. As an alternative to fire, we propose that fine-scale gap dynamics is the dominant process explaining the structure and dynamics of most unmanaged stands in the province's wet coastal temperate rain forests. Improved understanding of the spatial and temporal attributes of disturbance regimes in coastal forests has important implications for sustainable forest management and conservation of biodiversity."

Hallett, D.J. 2001. Holocene fire history and climate change in southern British Columbia, based on high-resolution analyses of sedimentary charcoal. PhD thesis. Simon Fraser Univ., Dep. Biol., Burnaby, B.C.
www.collectionscanada.gc.ca/obj/s4/f2/dsk4/etd/NQ81656.pdf

"Little is known about the role of fire in the cool and wet mountain hemlock rainforests located in the Coast and Cascade Mountains of southern British Columbia (BC). Macroscopic charcoal accumulation rates (CHAR) from radiocarbon-dated lake sediment cores were used along with 102 accelerator mass spectrometry (AMS) ages on soil charcoal to reconstruct long-term fire histories around two lakes. Fires were rare at the mountain hemlock sites, with intervals between fire events ranging from centuries to millennia. In the Frozen Lakes watershed, 18 of 40 fires (45%) in the last 9000 years are identified as local events, based on soil charcoal AMS ages. In the Mt. Barr Cirque Lake watershed, 11 of 46 fires (24%) in the last 7500 years are identified as local events. CHAR peaks lacking evidence of local fire likely represent extra-local fires. Overall fire frequency around both Frozen and Mt. Barr Cirque lakes has varied with climate throughout the Holocene, with 6–8 events/1000 years between 11,000 to 8800 cal years BP at Frozen Lake during the dry and warm early Holocene. Fires decrease to 3–5 events/1000 years from 8800 to 6400 cal years BP around both lakes as rainforest is established in the region. A variable fire period with a range of 2–8 events/1000 years occurs between from 6400 to 3500 cal years BP.

A synchronous decrease to 3–5 events/1000 years from 3500 to 2400 cal years BP corresponds with Neoglacial advances in the region. A dramatic return to more frequent fire (5–8 events/1000 years) from 2400 to 1300 cal years BP suggests that prolonged summer drought occurred more often during this interval. Modern fire frequencies of 2–5 events/1000 years were established after 1300 cal years BP. The timing of frequent fire episodes in mountain hemlock, western hemlock and montane spruce forests across southern BC correspond with century-scale solar activity maxima inferred from the atmospheric Δ^{14}C record. Spectral analysis revealed significant periodicities at ~218 years in the 11,000-year Frozen Lake CHAR record, and at ~210 years in Dog Lake and Clayoquot Lake CHAR over the last 1000 years. Synchronous fire response at widely separated sites coupled with common periodicities support a proposed link between fire events, drought and ~ 206-year solar variations. These findings, along with general circulation model results at 50° N, support an atmospheric mechanism where century-scale solar forcing strengthens the subtropical Pacific High and increases the potential for drought and forest fire ignition in wet coastal forests. Subdecadal sampling of lake sediment resolved CHAR peaks that compared well with modern stand-origin maps and fire-scar dates around Dog Lake, in the montane spruce zone of southeastern BC. CHAR peaks indicate frequent stand-destroying fires during the Medieval Solar Maximum between AD 900–1300. Large fires were also identified at ~ AD 1610 and 1800, supporting a link between century-scale solar maxima, drought and forest fire events at 50° N latitude. Accumulation rates of *Chara globularis* oospores were used to infer changing lake levels in Dog Lake. Low accumulation rates inferring lower water levels correspond to times of drought and frequent fire in western North America, while high lake levels correspond to wetter climate periods with little or no fire activity."

Hallett, D.K., D.S. Lepofsky, R.W. Mathewes, and K.P. Lertzman. 2003. 11 000 years of fire history and climate in the mountain hemlock rain forests of southwestern British Columbia based on sedimentary charcoal. Can. J. For. Res. 33(2):292–312. www.nrcresearchpress.com/doi/abs/10.1139/x02-177

"Little is known about the role of fire in the mountain hemlock (*Tsuga mertensiana* (Bong.) Carrière) rain forests of southern British Columbia. High-resolution analysis of macroscopic charcoal from lake sediment cores, along with 102 accelerator mass spectrometry (AMS) ages on soil charcoal, was used to reconstruct the long-term fire history around two subalpine lakes in the southern Coast and North Cascade Mountains. AMS ages on soil charcoal provide independent evidence of local fire around a lake and support the interpretation of peaks in lake sediment charcoal as distinct fire events during the Holocene. Local fires are rare, with intervals ranging from centuries to several millennia at some sites. Overall fire frequency varied continuously throughout the Holocene, suggesting that fire regimes are linked to climate via large-scale atmospheric circulation patterns. Fires were frequent between 11 000 and 8800 calendar years BP during the warm and dry early Holocene. The onset of humid conditions in the mid-Holocene, as rain forest taxa established in the region, produced a variable fire period until 3500 calendar years BP. A synchronous decrease in fire frequency from 3500 to 2400 calendar years BP corresponds to Neoglacial advances in the region and cool humid climate. A return of frequent fire between 2400 and 1300 calendar years BP suggests that prolonged summer drought occurred more often during this interval, which we name the Fraser Valley Fire Period. The present-day fire regime was established after 1300 calendar years BP."

Klinka, K. and C. Chourmouzis. 2001. The mountain hemlock zone of British Columbia. Univ. British Columbia, For. Sci. Dep., Vancouver, B.C. https://circle.ubc.ca/handle/2429/760

"Based on the presence of charcoal deep in the forest floor, the presence of living or dead western white pines, and fire scars on Alaska yellow-cedar, some 'uniform, even-sized' stands probably developed after fires 200 or more years ago. In other stands downed trees are present on and in the forest floor, suggesting stand originating windthrow events. The signs of both types of disturbance are clearly evident in a few existing young stands (50 to 150 years old)."

Lepofsky, D. 1999. The natural and cultural fire history of the central and upper Fraser River valley. For. Renewal BC, Res. Program. Simon Fraser Univ., Dep. Archaeol., Burnaby, B.C. www.for.gov.bc.ca/hfd/library/frbc1999/frbc1999mr114.pdf

"This project presents the first long-term reconstruction of fire frequency for the Mountain Hemlock Zone in Coastal British Columbia. Our Holocene fire history records of natural and cultural fire in these forests were reconstructed using radiocarbon dating of charcoal in forest soils and lake sediment charcoal from small deep lakes. These methods were developed in order to learn more about the long-term disturbance history of Mountain Hemlock forests and to try to distinguish between natural and cultural fires in these ecosystems.

Our results show a continuously varying fire frequency throughout the Holocene with three important periods where fire is more frequent than today. The first period occurs during the early Holocene (11,000 to 8200 calendar years BP) when summer insolation was higher than today. The second and third periods occur from 4500 to 3500 cal years BP and 2400 to 1200 cal years BP. The most recent high fire frequency period coincides with an intensification of cultural activity in the Fraser Valley. Our project is now using fossil pollen and plant macrofossil analysis to reconstruct any vegetation changes that occurred during these frequent fire periods."

Lertzman, K.P. 1989. Gap-phase community dynamics in a subalpine, old growth forest. PhD thesis. Univ. British Columbia, Dep. Zool., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/29177

"Small-scale natural disturbances involving the death of one to a few trees and creating gaps in the forest canopy are critical to the population and community ecology of many forest types. I studied the role of canopy gaps in the structure and dynamics of a high-elevation, old growth forest in coastal British Columbia. The research was conducted in four stands at Cypress Provincial Park (~1,100 m) occupying the transition from the upper montane ecosystems of the Coastal Western Hemlock Zone to the lower elevations of the Mountain Hemlock Zone. They contained four tree species: Pacific silver fir (*Abies amabilis*), western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), and Alaska yellow-cedar (*Chamaecyparis nootkatensis*).

Though the stands varied in the proportions of each species, all had a similar distribution of area under closed canopy (29%) and in gaps (52% expanded gap; 18% canopy gap). The overstory of two stands was dominated by Pacific silver fir and western hemlock, and two had a more equitable distribution of species. Pacific silver fir was much more dominant in the sapling layer (81%) than the canopy layer (43%) in all stands. Western hemlock was the next most frequent species among saplings (13%). Growth rate among Pacific silver fir saplings was greater in both classes of gap than it was under closed canopy. The distribution of saplings was independent of canopy classes, but there was a significant interaction between sapling species and rooting substrate. Western hemlock saplings were largely restricted to stumps, whereas firs occurred on stumps and on the forest floor. Most fir saplings (81%) showed evidence of suppression, and 23% had experienced multiple periods of suppression and release.

Most gaps had more than one gapmaker (90%). Half of all gapmakers died standing, and only 13% were windthrown. Pacific silver fir was represented among gapmakers in a much higher proportion than among canopy trees in general (64% vs. 45%). Median canopy and expanded gap areas were 41 and 203 m^2, respectively. The estimated forest turnover time varied from 280–1000 years depending on assumptions about the time taken for gaps to be filled. The most likely range is 600–700 years."

Lertzman, K.P. 1992. Patterns of gap-phase replacement in a subalpine, old-growth forest. Ecology 73(2):657–669.
http://cef-cfr.ca/uploads/Actualit%E9/Lertzman3.pdf

"Small-scale natural disturbances involving the death of one to a few trees and creating gaps in the forest canopy are key processes in the population and community ecology of many forests.

I examined the patterns of replacement in gaps in a subalpine old-growth forest in southern coastal British Columbia to assess their role in the forest community. I found no evidence that self replacement or reciprocal replacement act to maintain the current community composition. Gapmaker–gapfiller comparisons indicated preferential replacement of all species by Pacific silver fir (*Abies amabilis*), suggesting that the community is undergoing successional change. Nor did gap size, location within a gap, or local canopy composition appear to exert a strong influence on the species composition of regeneration within the gap. The only circumstance where Pacific silver fir was not overwhelmingly dominant among gapfillers was on stumps, where almost all successful western hemlock (*Tsuga heterophylla*) gapfillers were located. These patterns suggest that neither species-specific interactions between gapmakers and gapfillers nor variability in gap environments is adequate to maintain the current composition of the forest canopy. However, caution is indicated in projecting a long-term trend from this short-term assessment of community trajectory."

Lertzman, K., D. Gavin, D. Hallett, L. Brubaker, D. Lepofsky, and R. Mathewes. 2002. Long-term fire regime estimated from soil charcoal in coastal temperate rainforests. Conservation Ecol. 6(2):5. www.consecol.org/vol6/iss2/art5

"Coastal temperate rainforests from southeast Alaska through to southern Oregon are ecologically distinct from forests of neighboring regions, which have a drier, or more continental, climate and disturbance regimes dominated by fires. The long-term role of fire remains one of the key outstanding sources of uncertainty in the historical dynamics of the wetter and less seasonal forests that dominate the northerly two thirds of the rainforest region in British Columbia and Alaska. Here, we describe the long-term fire regime in two forests on the south coast of British Columbia by means of 244 AMS radiocarbon dates of charcoal buried in forest soils. In both forests, some sites have experienced no fire over the last 6000 years and many other sites have experienced only one or two fires during that time. Intervals between fires vary from a few centuries to several thousand years. In contrast to other conifer forests, this supports a model of forest dynamics where fires are of minor ecological importance. Instead, forest history is dominated by fine-scale processes of disturbance and recovery that maintain an ubiquitous late-successional character over the forest landscape. This has significant implications for ecosystem-based forest management and our understanding of carbon storage in forest soils."

Lertzman, K.P. and C.J. Krebs. 1991. Gap-phase structure of a subalpine old-growth forest. Can. J. For. Res. 21(12):1730–1741. www.nrcresearchpress.com/doi/abs/10.1139/x91-239

"We examined four stands in a subalpine old-growth forest in the Coast Mountains of southwestern British Columbia for gap-phase structure. Though the stands varied in the proportions of each species, all had a similar distribution of area under closed canopy and in gaps (overall means: 29% closed canopy, 52% expanded gap, 18% canopy gap). Median areas of canopy gaps and expanded gaps were 41 and 203 m^2, respectively. Most gaps (90%) had more than one gap maker, and gap makers within a gap were often from mortality events separated in time. Half of all gap makers died standing, and only 13% were windthrown. Pacific silver fir (*Abies amabilis* (Dougl.) Forbes) was represented among gap makers in a much higher proportion than among canopy trees in general (64 vs. 45%). The estimated forest turnover time varied from 280–1000 years, depending on assumptions about the time taken for gaps to be filled. Distinctive features of gap-phase structure and dynamics in this forest are the high proportion of area in gap, small gap size, multiple gap makers of varying stages of decay, and long tenure of gaps before they are filled."

Parish, R. and J. Antos. 2004. Structure and dynamics of an ancient montane forest in coastal British Columbia. Oecologia 141(4):562–576. www.springerlink.com/content/jdwfttq09hxx7qnh/

"Old-growth forests are common in the snowy, montane environments of coastal western North America. To examine dynamics of a stand containing four canopy tree species (*Abies amabilis, Chamaecyparis nootkatensis, Tsuga mertensiana* and *T. heterophylla*), we used four stem-mapped, 50 m × 50 m plots. From measurements of annual rings, we obtained ages from basal discs of 1,336 live trees, developed master chronologies for each species, reconstructed early growth rates, and delineated periods of release. The stand was ancient; individuals of all four species exceeded 900 years in age, and the oldest tree exceeded 1,400 years. The four plots differed in the timing of events, and we found no evidence of major, stand-level disturbance. Instead the stand was structured by small-scale patch dynamics, resulting from events that affected one to several trees and initiated episodes of release and relatively rapid early growth. The species differed in age structure and dynamics. *A. amabilis* and *T. heterophylla* had a classical reverse-J age structure indicative of stable populations, whereas *C. nootkatensis* and *T. mertensiana* appeared to rely on local episodes of increased recruitment, which were often separated by centuries, and were probably related to multiple-tree gaps that occurred infrequently. However, such gaps could be considered normal in the long-term history of the stand, and thus these species with their long life spans can persist. Most individuals of all four species grew extremely slowly, with trees typically spending centuries in the understory before reaching the canopy, where they were able to persist for additional centuries. Thus, the key features of this forest are the very slow dynamics dominated by small-scale events, and the slow growth of stress-tolerant trees."

Parish, R. and J. Antos. 2006. Slow growth, long-lived trees, and minimal disturbance characterize the dynamics of an ancient, montane forest in coastal British Columbia. Can. J. For. Res. 36:(11):2826–2838. www.nrcresearchpress.com/doi/abs/10.1139/x06-166

"Elucidating the factors that structure very old forests is crucial to understanding their dynamics. We reconstructed the history of an ancient (1000-year-old) stand in the mountains of coastal British Columbia that contained four tree species (*Abies amabilis* (Dougl.) Forbes, *Chamaecyparis nootkatensis* (D. Don) Spach., *Tsuga mertensiana* (Bong.) Carr., and *Tsuga heterophylla* (Raf.) Sarg.) in the canopy and the seedling bank. Using dendrochronological procedures, we examined the growth patterns of all trees (>4.0 cm diameter at breast height) in four 0.25 ha mapped plots. We also sampled the seedling bank in the four plots. Age structures indicated variable but rather continuous recruitment for all species. Periods of increased amounts of release or rapid early growth occurred but were not pronounced. Overall, we found little evidence for stand-level disturbance or the formation of large gaps. All four tree species appear able to persist in the stand in the absence of major stand-level disturbance, but the mechanisms contributing to coexistence differ. One species, *C. nootkatensis*, depends primarily on vegetative reproduction for persistence. Single-tree gap dynamics have predominated in the stand for centuries, placing this stand at the far end of the gradient from forests controlled by large, severe disturbances to those where very small-scale processes predominate."

SPRUCE – WILLOW – BIRCH BIOGEOCLIMATIC ZONE

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones of the Cassiar Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C. www.for.gov.bc.ca/hfd/library/documents/bib29004_book3.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal and north coastal forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The Cassiar Timber Supply Area contains a wide variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Some coastal sites are affected by fire very infrequently while interior boreal types are more susceptible to fire. Certain valley bottom alluvial sites have developed under the influence of primary successional processes but can nonetheless support fires. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones of the Cassiar Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib29004_book2.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the Cassiar TSA by dividing the SWB biogeoclimatic zone into four broad forest cover types for which nine post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones and subzones of the Fort Nelson Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib27061_book4.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The Fort Nelson Timber Supply Area contains a wide variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Some alluvial sites have developed under the influence of primary successional processes but can nonetheless support fires. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones and subzones of the Fort Nelson Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib27061_book3.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the Fort Nelson TSA by dividing the SWB biogeoclimatic zone into four broad forest cover types for which 10 post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Parminter, J. 1983. Fire history and fire ecology in the Prince Rupert Forest Region. In: Prescribed fire–forest soils symp. proc.. Mar. 2–3, 1982, Smithers, B.C. R.L. Trowbridge and A. Macadam (compilers and editors). B.C. Min. For., Inf. Serv. Br., Victoria, B.C. Land Manag. Rep. 16. pp. 1–35.
www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Lmr016.htm

"Fire ecology knowledge is required for fire management operations as well as for other aspects of natural resource management. Natural fire has influenced ecosystem processes at various scales and has been a major factor in determining the composition and distribution of vegetation types. Different fire types and frequencies can be classed into fire regimes and these regimes related to the role of fire in different ecosystems.

Forest tree species and other vegetation possess varying degrees of fire tolerance and fire adaptations, or indeed may be totally dependent on fire for their continued existence. On the other hand certain vegetation species are fire sensitive and may be removed altogether or lessened in numbers by fire. It appears that fire has played a diverse role in the biogeoclimatic zones of the Prince Rupert Forest Region – from very rare in the Coastal – Cedars – Pine – Hemlock to very common in the Boreal White and Black Spruce. Post-fire vegetation development can follow one of several directions, the direction taken is determined by site characteristics, the nature of the fire, and subsequent environmental conditions.

Significant differences may exist between the natural fire regime and historical fire effects and the fire regime and fire effects imposed by man and his various land management activities. Guidance in the artificial application of fire can be obtained from a knowledge of the natural place of fire in the ecosystem in question."

"Fires have been less frequent and less extensive in the SWB although charcoal in the soil profile can usually be found, attesting to fire's presence. Large fires are possible as indicated by the upper Stikine/Chukachida area, although fire spread is probably limited in most cases by topography and fuel discontinuities. Fires may originate in the SWB or be driven into it from the lower slopes. Surface fires have occurred in the area east of Atlin although these were likely man-caused. Prescribed burning is locally common, such as in the Kechika drainage."

Parminter, J. 1984. Fire-ecological relationships for the biogeoclimatic zones of the northern portion of the Mackenzie Timber Supply Area. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib25174_book3.pdf

"Detailed information related to the fire-ecological relationships of British Columbia's boreal and central northern forests has not been available in the past. The extensive nature of the resource and the prevalence of forest fires necessitates examination of basic ecological processes. The northern portion of the Mackenzie Timber Supply Area contains a variety of terrain and vegetative cover types. The majority of the forests of the area have developed under a lightning-maintained regime of periodic forest fires and much of the vegetation is in some way adapted to post-fire recovery. Within a framework defined by the biogeoclimatic zones of the area the post-fire successional development sequences for the major vegetative cover types are described. Given a knowledge of ecosystem characteristics, productivity levels, and response to fire, land managers can then consider the desired land management objectives to develop land and fire management plans."

Parminter, J. 1984. Fire-ecological relationships for the biogeoclimatic zones of the northern portion of the Mackenzie Timber Supply Area: summary report. B.C. Min. For., Prot. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib25174_book2.pdf

This report summarizes what is known about fire history, fire ecology, and vegetation succession for the northern Mackenzie TSA by dividing the SWB biogeoclimatic zone into three broad forest cover types for which nine post-fire successional models are shown. The major stages are newly burned–tree establishment; herbs, shrubs, and young trees; and tree stages. Prescribed burning is also discussed.

Pojar, J. and A.C. Stewart. 1991. Spruce – willow – birch zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 251–262.
www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap17.pdf

"It appears that wildfires have been less frequent and extensive in the SWB than in the adjacent BWBS, and extensive seral stands of lodgepole pine are uncommon though they do occur, as in the upper Jennings – Little Rancheria rivers."

Alfaro, R., E. Campbell, and B. Hawkes. 2010. Historical frequency, intensity and extent of mountain pine beetle disturbance in British Columbia. Can. For. Serv., Pac. For. Cent., Victoria, B.C. Mountain Pine Beetle Work. Pap. 2009-30.

http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/31405.pdf

"The history of mountain pine beetle outbreaks was reconstructed from increment cores and basal disks collected from 85 stands across British Columbia and Alberta. Using aerial survey data, dendrochronological software was calibrated to detect growth releases that could be attributed to beetle outbreaks. In addition to the outbreak in the 1970s and 1980s, growth release data indicate that beetle outbreaks probably also occurred in the late 1870s and 1900s, and in the 1930s and 1940s. Growth release periods associated with beetle outbreaks lasted up to 20 years, with the magnitude of growth increases averaging 58% to 65%. Based on time intervals between growth release periods, we estimated a return-interval of beetle outbreaks of 30 to 40 years. Although the intensity of past beetle outbreaks appears to be greater in central British Columbia than further north or in Alberta, further investigations are required. A histogram of growth release frequencies among stands suggests outbreaks have become more extensive over the last century."

"Relationships between the occurrence of beetle outbreaks and fire history were undertaken using several approaches in dendrochronology. Dating of fire scars in the Cariboo–Chilcotin Plateau of central British Columbia indicated that fires were much less frequent in the 20th century than they were in the 19th century. This may explain the more extensive outbreaks of the 1930s and 1940s and 1970s and 1980s in this region. Stands in regions characterized by low- or mixed-severity fire regimes had more frequent outbreaks than those in regions where fires are stand-replacing disturbance events. Among stands that originated from stand-replacing fires, we found that the time since fire had an important influence on frequency of beetle outbreaks—outbreaks were most frequent in stands 50 to 100 years after fire, when mature trees are less resistant to beetle attack and thick phloem tissues promote beetle development."

Applied Ecosystem Management Ltd. 2002. Characterising fire regimes in sub-boreal landscapes: fire history research in SBPS and SBS biogeoclimatic zones of Cariboo Forest Region. Prepared for Lignum Ltd., Vancouver, B.C. Unpubl. rep.

"Two major Biogeoclimatic subzones are contained within the Study Area, the majority being SBPSxc to the west and south, bordering on the IDFdk4, and SBPSdc to the east. Together, the SBPSxc and SBPSdc comprise 97% (70% and 27%, respectively) of the Study Area. SBPSmk encompasses the remaining 3% of the eastern margin of the Chilcotin Study Area."

"Based on time-since-fire data for the period 1961 – 1869, a fire cycle of 101.6 years is calculated for the Chilcotin Study Area. Based on individual fire mapping for the same time period, a fire cycle of 47.3 years is calculated.

Based on time-since-fire data for the period 1961-1869, rate of burning averages 0.99%/year for the Chilcotin, with more than 50% of the Study Area being affected by single fire events. Based on individual fire mapping, 2.11%/year has been affected by fire.

Based on both time-since-fire and individual fire mapping, fire suppression efforts appear to have been successful at decreasing the frequency and size of fire events within the study area during the past 30-40 years. When fire cycle is calculated through the inclusion of the period of fire suppression, present – 1962, a fire cycle of 145.2 years (time-since-fire data) and 67.9 years (individual fire map data) is found. The rate of burning during the 40-year period of fire suppression has been 0.01%/year.

Fire return interval, calculated based on site-specific analysis of fire scars, shows a mean fire return interval for Chilcotin Study Area of 47.9 years (±29.4 years). Mean fire return intervals were found to be significantly shorter in the SBPSxc (44.7 years ±26.4 years) versus the SBPSdc (63.9 years ±40.0 years). No major differences in return intervals were found between upland and lowland landscape position, or between upland till and upland glaciofluvial landscape types."

Dawson, R. 1997. Natural disturbance patterns in the Cariboo Forest Region—summary of results. For. Renewal BC, Res. Program. B.C. Min. For., Cariboo For. Reg., Williams Lake, B.C.
www.for.gov.bc.ca/hfd/library/frbc1997/frbc1997mr158.pdf

"The study area sampled in year one of this project included twenty-three 1:20,000 forest cover maps sheets covering an area of approximately 3400 km^2. The study area is located west of the Fraser River on the Chilcotin plateau south of the Itcha Mountain Range. It includes 1520 km^2 in the SBPSxc, 1855 km^2 in the MSxv, 18 km^2 in the ESSFxv and 6 km^2 in SBPSdc and includes most of the area within three draft landscape units. This area is representative of the cold dry climatic conditions found on much of the Chilcotin Plateau."

"A very simplistic analysis of the data indicates that approximately 75% of the area of forested land is under 140 years of age and that over one half of the area is made up of age class patches greater than 1000 ha in size. Although detailed interpretations will have to consider a number of important factors which influence this data, this simplified analysis portraying a disturbance regime characterized by frequent, large fires corresponds to that hypothesized by local ecologists. Two important factors which will have to be considered in further interpretations include the effects of fire suppression over past 40 years and the fact that the forest cover data information used to generate this analysis was not designed to provide accurate estimations of seral age, especially for the older age classes.

The size, frequency and arrangement of forest remnants (older forest patches within a matrix of younger forests) is an interesting result of the natural disturbance history and an important aspect of the landscape pattern from an ecological viewpoint. These remnant patches are thought to play an important ecological role by acting as refugia and 'infection' sources for organisms to recolonize the surrounding disturbed area. They also provide horizontal habitat diversity and provide islands of habitat which may serve as 'stepping stones' for animal movements. In the study area, remnants covered 5.5% of the total forested area and averaged approximately 13 ha in size with much variation around the mean. We have to be aware that many smaller remnants may be below the size resolution provided by the forest inventory database and would therefore be missed by this analysis."

"The data show that 46% of the total study area is composed of forests greater than 100 years of age and that the mature/old component is predominantly in large patches with a high proportion of interior forest. Seventy-eight percent (35/45 as a percent) of this mature and old forest is in patches over 1000 ha in size. Sixty-nine percent (31/46 as a percent) of this mature/old forest is 'interior forest'" buffered from the forest edge.

Douglas, K.L. 2001. Historical analysis of fire intervals of two biogeoclimatic units in the central Chilcotin, British Columbia. BSc thesis. Univ. Northern British Columbia, Prince George, B.C.

"Historical variability in lodgepole pine fire intervals is a necessary consideration for management that aims at maintaining natural biodiversity across forested landscapes. This fire history study examined fire-scarred lodgepole pine cross-sections collected from the dry cool Interior Douglas-fir (IDFdk) and the very cold Sub-Boreal pine – Spruce (SBPSxc), two biogeoclimatic units of British Columbia. Fire years were determined by counting growth rings and then adjusting fire dates based on synchronization with fire dates of adjacent trees. The IDFdk unit had a Weibull Median Interval (WMI) of 12.88 years, with minimum and maximum fire intervals of 5 and 44 years, respectively. The SBPSxc unit had a WMI of 9.29 years, with minimum and maximum fire intervals of 1 and 50 years, respectively. The relatively short fire intervals suggest that fires were likely of low to moderate intensity between the 1830s and mid-1900s. The presence of more than one fire scar on individual cross-sections also suggests that fire intensity was not extreme. When fire intervals of the biogeoclimatic units were compared against each other, it was found that no significant difference exists between the fire intervals."

Francis, S.R., S. Skinner, and D. Conly. 2002. Understanding mixed severity sub-boreal fire regimes in the Chilcotin region of British Columbia, Canada. In: 4th Int. workshop on disturbance dynamics in boreal forests: disturbance processes and their ecological effects. Aug. 9–14, 2002, Prince George, B.C.

"Fire regimes can be characterised by the size, frequency and severity attributes of cumulative fire disturbances over periods of time. A large amount of fire history research has focused on the temporal aspects of fire regimes through the quantification of fire return intervals. While this information is important, both from an ecological and management perspective, it should be recognised that fire frequency only describes one aspect of a fire regime. Gaining an understanding of the spatial and severity attributes of historical fire patterns is critically important to gaining a full appreciation for the 'total' fire regime. This presentation describes the results of a recently completed fire history study within a portion of the Lignum Ltd. Innovative Forest Practices Agreement (IFPA) in two Sub-Boreal Pine and Spruce biogeoclimatic subzones (SBPSxc and SBPSdc) of the Chilcotin Plateau in central British Columbia, Canada. Using the period 1820 – present, a mean fire return interval of approximately 47 years was calculated for the entire project area.

However, interpreting this statistic without the added context of fire severity and size is misleading. Fire sizes ranged between one and greater than 100 000 ha and individual fire events burned with a range of severities from underburning to complete stand-replacing, creating and maintaining a complex forest mosaic. Individual fire disturbance patches were examined for levels of residuals, which allowed relationships between severity, size and frequency to be quantified. This information, when set in a landscape context, provides critical information for natural disturbance–based forest management planning regimes. Results of this project are being used to guide Lignum Ltd.'s short and long-term ecosystem management strategies for stand and landscape-level harvesting objectives."

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"The SBPS landscape is dominated by extensive lodgepole pine forests and abundant wetlands. Smaller areas of spruce and trembling aspen forests are present and small grasslands and meadows occur locally. The abundance of wetlands is due to poorly developed drainage patterns. Late seral or climax vegetation on zonal sites is a lodgepole pine or lodgepole pine – spruce forest. The spruce is primarily hybrid white spruce except in the driest parts of the zone (SBPSxc) where the spruce is typically white spruce. Due to extensive fire history, most stands are young (<140 years), even-aged, and often dense."

"Climax tree species on zonal sites in the SBS Zone are hybrid white spruce and subalpine fir. However, due to frequent wildfires in the past, climax stands are uncommon at low to moderate elevations (<1200 m). Lodgepole pine is the principal seral species throughout the zone. Douglas-fir is also a common seral species at low elevations (<1000 m) but it is seldom abundant at higher elevations."

"The SBPSdc occurs west of the Fraser River in the north-central portion of the Cariboo Forest Region where the Coast Mountains rainshadow is less pronounced than southward in the SBPSxc. It occurs about as far south as Palmer Lake and as far west as Kluskus Lakes." On zonal sites "the vegetation is mostly even-aged lodgepole pine stands, which occur in a patchwork of age classes, stem densities, and stand sizes, depending on fire history. Small aspen stands are locally present. Although hybrid white spruce is in the understory of most stands, the dominance of pine has been maintained by frequent fires and relatively slow rates of succession."

Steen, O. and D.A. Demarchi. 1991. Sub-boreal pine – spruce zone. In: Ecosystems of British Columbia. D.V. Meidinger and J. Pojar (editors). B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. Ser. 06, pp. 195–207.
www.for.gov.bc.ca/hfd/pubs/docs/Srs/Srs06/chap13.pdf

"Upland coniferous forests dominate the SBPS landscape. Lodgepole pine is by far the most common tree species and, in fact, large areas of the forest contain no tree species other than lodgepole pine. Owing to an extensive fire history, the pine trees are generally young, even-aged, and often dense. Productivity of the forest is severely limited by the harsh climate."

"White spruce is the theoretical climatic climax tree species over most of the SBPS. In the very dry southwestern part of the zone, however, the abundance of pine regeneration and the virtual absence of spruce regeneration on zonal sites suggest that lodgepole pine is the climatic climax tree species. In the remainder of the zone, the dominance of pine on zonal sites has been maintained by recurrent wildfires, and pine is considered a persistent fire-climax species. In the absence of fire, succession to spruce dominance would be very slow."

"The Sub-Boreal Pine – Spruce zone has a history of frequent wildfires. Effects of these fires are evident in the patchwork of different aged stands and the small number of stands more than 120 years old. A recent mountain pine beetle epidemic has resulted in extensive mortality of pine trees in the SBPS, especially in the southwest."

Steventon, D. 1997. Historic disturbance rates for interior biogeoclimatic subzones of the Prince Rupert Forest Region. B.C. Min. For., Prince Rupert For. Reg., Smithers, B.C. Exten. Note 26.
www.for.gov.bc.ca/rni/research/Extension_notes/Enote26.pdf

"One important parameter of natural disturbance regimes is the frequency at which stand initiating events such as severe fire have historically occurred, and how this has shaped the age structure of forest landscapes. In this note, using the forest inventory database, I examine the historic rate of stand initiating disturbances in the SBPSmc, SBSdk/mc and ESSFmc/wk/mk Biogeoclimatic (BEC) subzones of the Lakes, Morice and Bulkley forest districts, Prince Rupert Forest Region."

Stand-initiating disturbance rates were calculated using all age data and then truncated age data, which account for possible biases in assigning ages to stands older than 160 years. Results were as follows: SBPSmc: 91 and 92 years; SBSdk: 93 and 95 years; SBSmc: 124 and 148 years; ESSFmc: 166 and 284 years; ESSFmk: 337 and 810 years; and ESSFwv: 220 and 1150 years (for all age data and truncated data, respectively). The considerable differences for the last two ESSF subzones are due to the large areas of stands older than 240 years for which the true ages are not known.

Vera, P. 2001. Fire history and ecology of remnant forest patches in the subboreal pine spruce zone of central British Columbia. MSc thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/11597

"When a fire burns a substantial area of forest, it often leaves patches unburned. No published study appears to have addressed the question of whether or not there are patches that have never been burned by fires within the last few hundred years in British Columbia. Published studies have only partially addressed the question of whether or not there are some landscape factors that prevented fire from killing trees within the unburned patches. To address these questions, a project commenced in 1999 in the SBPSxc biogeoclimatic subzone with 2 main objectives – to determine (1) if there are some forest patches within lodgepole pine forests in this subzone in central B.C. that have not burned during the last 200–300 years, and (2) if forest patches within these lodgepole pine forests that did not burn at the time when the surrounding forests were most recently burned, have some characteristics that caused them not to burn. It was determined that in 24 of 26 patches studied, the most recent fire within the patch was the same one that established the surrounding forest. All patches had burned within the last 200–300 years. It is not completely certain why trees in the study patches escaped being killed during the fire that established the surrounding forest. It appears that lower tree density and basal area within the patches at the time of the fire may have been important. Other factors such as topographic features, soil moisture, and crown fuels do not appear to have been important."

SUB-BOREAL SPRUCE BIOGEOCLIMATIC ZONE

Andison, D.W. 1996. Managing for landscape patterns in the sub-boreal forests of British Columbia. PhD thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/6238

"Forest managers in North America are attempting to incorporate a growing number of ecological issues across many different temporal and spatial scales. In response, the traditional approach of managing for individual or groups of species and/or functions, is giving way to managing for a more natural time–space array of natural resources. Better known as 'landscape management,' the strategy relies heavily on understanding the historical, 'natural' processes and patterns at the landscape level. The objective of this dissertation is to develop a better understanding of the natural landscape-level dynamics of a fire dominated landscape in northern British Columbia.

The age-class distribution was used to show that stand replacing fires had a fire cycle of 80–100 years. Although stands much older than this average persist, there was strong evidence to suggest that very old stands become more susceptible to some form of disturbance. The most striking feature of the age-class distribution was its lack of stability.

Although the vast majority of disturbances were very small, and simple in shape, most of the landscape was comprised of very large disturbances. Forest fires were significantly more active in areas with the driest soils. It was also suggested that fire activity may be higher on south and west-facing slopes.

Information from the disturbance regime description was incorporated into a spatially explicit landscape model to create multiple landscape scenes of a 'natural' disturbance regime. Disturbance size limits and age eligibility restrictions were then imposed in simulation.

Generally as size and age restrictions increased, interior forest area decreased, edge density increased, age-class distribution favoured younger forests, spatial diversity increased, and temporal diversity decreased. The detailed results demonstrated the importance of using a variety of pattern metrics, in different forms, to grasp the full impacts of each type and degree of restriction.

The two methods of investigating sub-boreal landscape dynamics used in this research demonstrated the dangers of using single landscape 'snapshots' to represent 'natural' conditions. It also raises important questions with respect to the wisdom of management practices which artificially stabilize both spatial and temporal attributes of landscapes."

Applied Ecosystem Management Ltd. 2002. Characterising fire regimes in sub-boreal landscapes: fire history research in SBPS and SBS biogeoclimatic zones of Cariboo Forest Region. Prepared for Lignum Ltd., Vancouver, B.C. Unpubl. Rep.

"Three major Biogeoclimatic subzones account for 93% of the East Fraser Study Area; SBSdw1 (42%), SBSdw2 (22%) and SBPSmk (29%). A small portion of the SBSmc1 and SBSmh is also present and collectively account for 7% of the East Fraser Study Area."

"Based on time-since-fire data for the period 1961–1869 (92 years), a fire cycle of 98.9 years is calculated for the East Fraser Study Area. This is a very similar rate as calculated for the Chilcotin Study Area (101.6 years) using time-since-fire mapping for the same period of analysis. As was illustrated in the Chilcotin, fire overlap can contribute significant additional area to the 'true area burned,' resulting in a shortened fire cycle. However, considering the nature of the East Fraser forest mosaic (very large areas of even-aged forest with limited stand-level retention), it is probable that the extent of fire overlap would be less than documented in Chilcotin. In this situation, the time-since-fire mapping approach would provide a more accurate estimate of fire cycle.

Based on time-since-fire data for the period 1961-1869, rate of burning averages 1.01%/year for East Fraser, with more than 50% of the area being affected by a single fire event (1869), and two other events, 1922 and 1905, affecting at least 10% of the study area.

Similar to Chilcotin, East Fraser has been largely fire free since 1962, suggesting that fire suppression activities have been largely successful. However, a marked decrease in the rate of burning is also observed during the period 1961–1922, a period not under the influence of fire suppression."

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 26.
www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh26.htm

"Because of the pervasive fire history of this subzone (fire-free intervals longer than 300 years are rare and most stands are probably burned every 100 years, on average), lodgepole pine and trembling aspen form frequent and extensive seral stands – with pine more abundant on coarser-textured, more acidic soils, and aspen dominating on finer-textured soils. Paper birch and black cottonwood are also common seral species."

Bartemucci, P., K.D. Coates, K.A. Harper, and E.F. Wright. 2002. Gap disturbances in northern old-growth forests of British Columbia, Canada. J. Vegetation Sci. 13(5):685–696. http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2002.tb02096.x/abstract

"We characterized the abundance, size and spatial patterning of canopy gaps, as well as gap-forming processes and light availability in boreal, sub-boreal, northern temperate and subalpine old-growth forests of northwestern British Columbia. The proportion of area in canopy gaps ranged from 32% in northern temperate forests to 73% in subalpine forests. Evenly distributed developmental gaps were dominant but permanent openings created by edaphic components and by shrub communities were also common, particularly in sub-boreal forests. Abundant gaps, large gap sizes, high numbers of gap makers per gap and frequent gap expansion events suggest that gaps have long tenure in these forests. Snapped stems and standing dead mortality were the most common modes of mortality in all forest types resulting in little forest floor disturbance, creating few germination sites for seedling establishment. We found high mean light levels (16–27% full sun) and little difference between non-gap and gap light environments. Our results suggest that gap dynamics in these forests differ fundamentally from those in temperate and tropical forest ecosystems."

Bartemucci, P., K.D. Coates, K.A. Harper, and E.F. Wright. 2002. Gap dynamics in old-growth sub-boreal and boreal forests of northwestern British Columbia. In: 4th Int. workshop on disturbance dynamics in boreal forests: disturbance processes and their ecological effects. Aug. 9–14, 2002, Prince George, B.C., p. 26.

"Old-growth stands comprise 33 and 42% of the forest land-base in the sub-boreal and boreal forests of northwestern BC, respectively. Wildfire is the major catastrophic disturbance in this landscape; however, the extent and importance of small-scale disturbances in older stands are not well described. We characterized the abundance, size and spatial patterning of canopy gaps, as well as the major gap-forming processes. The proportion of area in canopy gaps was 57 and 50% in sub-boreal and boreal forests, respectively. Gap sizes ranged from 19 to 830 m^2 in sub-boreal forests and 9 to 542 m^2 in boreal forests. Gaps were characterized as developmental, shrub, combination (developmental and shrub) or edaphic. Developmental canopy gaps were the most common in both forest types. Shrub gaps, dominated by Sitka alder (*Alnus sinuata*) were common in sub-boreal forests. The abundance of gaps, the large gap sizes, the high numbers of gap makers per gap, and the frequency of gap expansion events suggest that gaps have long tenure in these forests. Snapped stems and standing dead mortality were the most common modes of mortality, resulting in little forest floor disturbance. We found little difference between non-gap and gap light environments (18 – 27% full sun)."

Campbell, K.A. 2006. Natural disturbance and climate variability in the dry cool sub-boreal spruce ecosystem of the central interior of British Columbia. PhD thesis. Univ. British Columbia, Fac. For., Vancouver, B.C. https://circle.ubc.ca/handle/2429/30758

"This research presents an evaluation of current sustainable forest management policies in British Columbia within the context of past, current and future disturbance regimes, and including the possibility of a changing climate, for a 1 million ha study area in the dry cool sub-boreal spruce ecosystem in the central interior of the province. In British Columbia, policy mandates that management should be consistent with the temporal patterns of natural disturbance processes. This research critically assesses such a policy from a number of perspectives, including an historical analysis, a modelling exercise of future conditions, and an examination of the relationship between climate and disturbances. Spatial disturbance data for fires and mountain pine beetle (1904–2004) were combined with vegetation data to create a comprehensive database of historical disturbances and landscape conditions in the study area; these data were used in all subsequent analyses. The historical and current range in variability in natural disturbances was characterized in order to make recommendations of refinements in BC's sustainable forest management policies. Compared to the time period 1904–1953, disturbance frequency was lower, return intervals were longer, and early seral stage forests have declined in more recent time periods (1954–2004). In most cases the current landscape does not meet the policy guidelines. There is a need, however, to make these policies species-specific rather than ecosystem-specific. A forest management model was used to examine the potential impact on the landscape of harvesting forests at the same rate as historical disturbances. Only after 130 years of such a harvesting or disturbance regime, did the landscape return to the historical range of variability in condition. The relationships between annual area disturbed, the Pacific Decadal Oscillation and (temperature and precipitation) climate variables over an 89-year time period were modelled using Poisson regression. Although broad-scale variables such as temperature and precipitation were important, so was the multidecadal cycling of finer scale processes such as the Pacific Decadal Oscillation. The main conclusion of this dissertation is that any analysis of the historical range of variability in disturbances, especially if it is being used to guide management policy, must include the effects of climate on disturbances."

Clark, D.F. 1994. Post-fire succession in the sub-boreal spruce forests of the Nechako Plateau, central British Columbia. MSc thesis. Univ. Victoria, Dep. Biol., Victoria, B.C.

"Natural fires have been of fundamental importance in controlling stand structure, composition, and biodiversity of forests over much of the interior of British Columbia. To evaluate the impact of management strategies on these ecosystem attributes it is useful to develop a thorough understanding of the effects of natural fires. A chronosequence approach was used to examine patterns of successional change following fires in a part of the sub-boreal spruce zone (SBS), that contains a diverse array of fire initiated stands of varying age.

Fifty-seven stands, which ranged in age from 11 to 438 years old and varied in both structure and composition, were sampled. Most stands began with a post-fire cohort comprised primarily of lodgepole pine (*Pinus contorta*), with lesser amounts of subalpine fir (*Abies lasiocarpa*) and interior spruce (*Picea glauca × engelmannii*). Other stands had post-fire cohorts composed almost exclusively of lodgepole pine, while a few stands had post-fire cohorts comprised primarily of subalpine fir and interior spruce. Although most stands appear to have resulted from stand initiating fires, 16 stands had trees that survived the last major fire. It is commonly assumed that understory trees die in conjunction with overstory trees in stand-destroying fires; however, an unexpected result was that ten of these stands had residual subalpine fir and interior spruce that survived as small trees even though all canopy trees appear to have died. Differences in stand histories and recruitment patterns are central to explaining these differences in succession.

Although the initial stand composition varies, subalpine fir and to a lesser extent interior spruce increases with time whereas lodgepole pine decreases. Eventually this results in the development of old-growth forests dominated by subalpine fir with lesser amounts of interior spruce. The volume of Coarse Woody Debris (CWD) is variable over the chronosequence, however, young stands have a greater proportion of small-sized pieces as compared to older stands. Vascular plant diversity is inversely related to stand age and is highest in the youngest stands and is consistently low in the old-growth stands. Herb cover declines over the chronosequence, whereas, shrub cover is highest in the young (ca. 100 yr.) and old (> 300 yr.) stands."

Clark, D.F., J.A. Antos, and G.E. Bradfield. 2003. Succession in sub-boreal forests of west-central British Columbia. J. Vegetation Sci. 14(5):721–732. http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2003.tb02204.x/abstract

"Structural and compositional changes were analysed over the course of 400+ yr of post-fire succession in the sub-boreal forests of west-central British Columbia. Using a chronosequence of 57 stands ranging from 11 to 438 yr in age, we examined changes in forest structure and composition with complementary PCA and DCA ordination techniques. To determine stand ages and timing of tree recruitment, approximately 1800 trees were aged. Most early successional forests were dominated by *Pinus contorta*, which established rapidly following fire. *Abies lasiocarpa* and *Picea glauca × engelmannii* were also able to establish quickly, but continued to establish throughout the sere. Few *Pinus contorta* survived beyond 200 yr, resulting in major changes in forest structure. In some stands *P. contorta* never established, which led to considerable variation among stands less than 200 yr old. The oldest forests converged on dominance by *Abies lasiocarpa*. Vascular plant diversity decreased during succession, whereas canopy structure became more complex as gap dynamics developed. Although these sub-boreal forests contain few tree species, successional changes were pronounced, with structure changing more than composition across the chronosequence."

DeLong, S.C. 1998. Natural disturbance rate and patch size distribution of forests in northern British Columbia: implications for forest management. N.W. Sci. 72 (Spec. Issue No. 1):35–48. www.vetmed.wsu.edu/org_nws/NWSci%20journal%20articles/1998%20files/Special%20addition%201/v72%20p35%20DeLong.pdf

"A common theme in current forest management policy is that harvesting should be designed to achieve the landscape patterns and habitat conditions that are maintained in nature by natural disturbance regimes. This study was undertaken to determine the influence of climate and topography on disturbance rate and patch size associated with stand replacement wildfire. The purpose was to provide new information to improve forest management guidelines based on approximating natural disturbances currently being implemented in British Columbia.

I modified stand age-class data from inventory records within a geographic information system in order to determine annual disturbance rate and patch size distribution for 9 areas differing in regional climate and topography (plateau vs. montane). Regression analysis was used to determine the influence of climate and gross topography on fire cycle. Patch size distribution was compared graphically and statistically.

Annual disturbance rate and patch size distribution in northern natural forests in British Columbia were clearly related to regional climate and topography. In montane landscapes, a decrease in disturbance rate, a decrease in mean patch size and a decrease in proportion of area in patches > 1,000 ha was associated with increasing precipitation. For plateau areas, topographic units with intermediate precipitation regime had higher disturbance rates and a greater proportion in patches > 1,000 ha. Montane areas which were climatically similar to adjacent plateau areas had a lower disturbance rate and less area in larger patches.

Current biodiversity guidelines appear to underestimate the fire cycle for many areas. Maximum allowable patch size in the current guidelines was lower than the maximum natural disturbance patch size determined for any of the landscapes examined. Current recommendations also suggest to manage for more area in 40–250 ha patches than was evident from the data."

Enache, M.D. 2006. Mid to late Holocene fire and climate dynamics inferred from lake sediments from Interior British Columbia, Canada. PhD thesis. Queen's Univ., Dep. Biol., Kingston, Ont.

"A number of distinct charcoal morphotypes were defined in this study and used along with diatom assemblages from lake sediments to investigate the relationships between fire and climate at decadal through millennial scales from the Interior British Columbia. Charcoal fragments were classified into seven distinct morphotypes according to their morphological and structural characteristics using optical microscopy. The contemporaneous relationship between charcoal morphotypes and recorded area burned was assessed from three lakes in different biogeoclimatic zones [ESSF, IDF, SBS] between 1919-2000. The distribution of each charcoal morphotype showed distinct differences over time. In Prosser Lake [IDF-ESSF boundary] type-M charcoal was significantly correlated to area burned around Prosser Lake at radii up to 20 km, whereas type-C morphotype was correlated to area burned at a radius <10 km, and type S at a 20-km radius. In Opatcho Lake, [SBS] morphotype M was the only charcoal type significantly correlated with area burned. Charcoal from Big Lake was inversely related to past area burned, suggesting important contribution from secondary deposition. The strong correlation between type-M charcoal and area burned was used to develop an index of area burned. The charcoal-morphotype approach at inferring past fires was further assessed by longer-term reconstructions of climate at a sub-decadal resolution over the past 400 years and centennial-scale resolution over the last six millennia in sediment cores from Opatcho Lake. Climate proxies were developed using variations in diatom assemblages and supported with regional proxies of temperature and precipitation. In both cases, the reconstructions indicates that synoptic-scale climate variations were significantly related to morphotype-based reconstruction of fire, but were not related to total charcoal. This new technique suggests that fires were ~5 times more common than present day between 4500-6000 yrs B.P., a well known period of aridity. Models suggest that B.C. will get increasingly arid. A similar fire regime to that observed in the mid Holocene should be expected."

Hawkes, B., W. Vasbinder, and C. DeLong. 1997. Retrospective fire study. Final rep. Fire regimes in the SBSvk and ESSFwk2/wc3 biogeoclimatic units of northeastern British Columbia. McGregor Model For. Assoc., Prince George, B.C.
www.resourcesnorth.org/publications/RetrospectiveFireStudy.pdf

"A retrospective study of fire was initiated in the north-eastern interior of British Columbia as a part of the McGregor Model Forest Association's larger goal to determine the ecological processes that influence the forest landscape in this area. The area of study encompassed approximately 1.3 million hectares of forested and mountainous terrain stretching along the western side of the Rocky Mountains within the SBSvk, ESSFwk2, and ESSFwc3 biogeoclimatic units. British Columbia Ministry of Forests digital forest inventory data was heavily relied upon to determine the age and patch characteristics of the study landscape. Using this data the objectives have been to address the knowledge gap regarding the historical fire regime in the study area. Estimates have been derived of historical patch size, patch shape, and rate of disturbance in the study landscape. Analysis has also included comparison of historical patch size estimates with fire records for the period 1950–1992, as well as an examination of the seasonality of fire occurrence for both natural and human-caused fires in this time period. Results of some sample plot data collected within the study area are also presented.

Results indicated that the fire cycle for these cool and wet mountainous subzones seems to be much longer than initially estimated and that both the SBSvk and ESSFwk2/wc3 biogeoclimatic units should be classified as NDT1 systems in the provincial Biodiversity Guidebook. Patch sizes within the study area exhibit a north–south difference with the northern half of the study area characterized by larger disturbance patches than the southern half of the study area. It appears as though the importance of very large patches in this landscape is underestimated in the Biodiversity Guidebook. Patch shape complexity differs significantly between the northern and southern sections of the study area. It is likely that the higher proportion of very large patches in the northern portion of the study area is contributing to this north–south difference."

Kneeshaw, D.D. 1992. Tree population dynamics of some old sub-boreal spruce stands. MSc thesis. Univ. British Columbia, Fac. For., Vancouver, B.C.
https://circle.ubc.ca/handle/2429/2992

"Disturbance at the scale of single trees shapes the development of boreal forest ecosystems, especially in 'overmature' or 'old-growth' stages, despite the acknowledged role of fire as a catastrophic agent of stand reinitiation. This study has reconstructed the population dynamics of fourteen Sub-Boreal Spruce stands (composed of *Picea engelmannii* × *glauca*, *Abies lasiocarpa* and lesser amounts of *Pinus contorta* and *Populus tremuloides*) since the last stand destroying wildfire. Identification of the post-disturbance cohort and subsequent recruitment provided a means of assessing the relative role of small-scale (single-tree) disturbance and large-scale, catastrophic disturbance on species composition and stand development.

The results suggest that SBS stands are self-perpetuating, and that although *Picea* may disappear from some stands it is maintained within forests of this zone. Presumably due to its high shade tolerance, *Abies* recruitment (when present) occurred uniformly throughout the stand's history. *Picea* ingress was associated with more exacting conditions, and it can return in sufficient numbers to perpetuate itself after long periods of exclusion. Minor disturbances were important in accelerating the reinitiation of *Picea* below the forest canopy. In many stands *Abies* was the most abundant species but this study suggests that although *Picea* regeneration often occurred in lower numbers it is maintained as a dominant overstory species due to poorer *Abies* recruitment to larger size classes.

In many of the stands there was evidence of an earlier *Populus* component that may have played an important role in conifer establishment after wildfire. The faster growing *Populus* may ameliorate harsh environmental conditions to the benefit of conifer regeneration. This process may be especially important in the Sub-Boreal Spruce zone where long periods of colonization (on average 75 years but up to 100 years) are common.

Another part of this project focused on defining the later stages of forest stand development in terms of tree population biology. Old-growth was recognized as the stage when the rate of tree regeneration and mortality, and thus age structure, are influenced more by single tree processes than by the stand initiating disturbance.... The tree population structures and old-growth attributes described for SBS stands suggest that this definition was a useful and objective ecological tool for ranking the later stages of stand development. In the SBS structural data was found appropriate for identifying the later stages of stand development through multivariate analysis. Attributes found to be strongly correlated with stand development, such as the number of large downed logs and snags, reflect the importance of single-tree mortalities to the old-growth stage."

Kneeshaw, D.D. and P.J. Burton. 1997. Canopy and age structures of some old sub-boreal *Picea* stands in British Columbia. J. Vegetation Sci. 8(5):615–625.

http://onlinelibrary.wiley.com/doi/10.2307/3237365/abstract

"14 old, unlogged, *Picea*-dominated stands in the moist cool Sub-Boreal Spruce biogeoclimatic subzone of central British Columbia, Canada, were sampled to describe canopy heterogeneity, regeneration patterns and tree population age structures. These stands are composed of *Picea engelmannii* × *glauca* hybrids, *Abies lasiocarpa* and lesser amounts of *Pinus contorta* and *Populus tremuloides*, and had survived 124–343 yr since the last stand-destroying wildfire. Canopy cover was patchy and highly variable (ranging from 30.5% to 86.4%) but was not significantly related to stand age. Vertical canopy structure was less variable, reflecting the shade-tolerance and live crown ratios (length of live canopy expressed relative to tree height) of component species: 18.8% for *Populus*, 20.2% for *Pinus*, 46.7% for *Picea* and 51.4% for *Abies*. Individual stands varied considerably in their population structures and in their stand development trajectories, yet some patterns are evident. Survivors of the initial post-disturbance cohort of trees took 51 to 118 yr (mean = 80, s.d. = 20) to establish. Some stands had all tree species present during stand initiation, while other stands indicated early successional roles for *Populus* and *Pinus*, or a late successional role for *Abies*. *Abies* recruitment, while often slow in the beginning, occurs uniformly throughout the history of most stands, reflecting the high shade-tolerance of this species. *Picea* is often recruited in high densities early in stand development, and then (after long periods of exclusion) may be displaced by *Abies* in some stands but maintains itself in others. Minor, single-tree disturbances (due to bark beetles, root rot, and windthrow) were important in accelerating the reinitiation of *Picea* in the understory. Results thus suggest that stands from this region can be self-perpetuating in the absence of fire. Yet, post-fire tree populations still clearly dominate these spruce–fir forests, for only the oldest stand had greater basal area in the replacement cohort than in the initial cohort."

Lewis, K.J. and S. Lindgren. 1999. Influence of decay fungi on species composition and size class structure in mature *Picea glauca* × *engelmannii* and *Abies lasiocarpa* in sub-boreal forests of central British Columbia. For. Ecol. and Manag. 123(2-3):135–143.

www.sciencedirect.com/science/article/pii/S0378112799000249

"Disturbance patterns in the sub-boreal spruce forests of central British Columbia have long been thought to result from frequent stand-initiating fires. However, recent evidence suggests that fires in the wetter areas of this region are infrequent (>500 years) and the uneven-aged stand structures have been shown to be self-maintaining in the absence of fire. The importance of decay fungi as agents of gap-formation and facilitators of uneven-aged stand structure was investigated. Three plots on each of two recently clearcut sites were established. Each stump in the plots was stem mapped and the species and diameter recorded. Decay at the stump top was recorded as white or brown rot, and the area occupied by decay was measured. Spruce stumps dominated the larger diameter classes but had less butt rot than sub-alpine fir stumps. Decay fungi contribute to stem breakage in living trees with heart rot, and as saprots of dead trees. Therefore, the results suggest that decay fungi play an important role in removing sub-alpine fir trees from the canopy of these wetter sub-boreal ecosystems, and in enabling spruce recruitment. The type of decay observed in sub-alpine fir suggests that breakage is predominantly due to white rot fungi causing heart rot, such as *Echinodontium tinctorium* and *Stereum sanguinolentum*. In spruce, brown rot fungi, which are predominantly saprot or wound-entry decay fungi, became more common in larger spruce, and may result from wounding as sub-alpine fir fall from the canopy. Spatial analysis indicated the stumps with stem decay were clumped. However, this is more likely due to strong clumping of the host, rather than spreading of butt rot pathogens through the roots."

Lewis, K.J. and S. Lindgren. 2000. A conceptual model of biotic disturbance ecology in the central interior of B.C.: how forest management can turn Dr. Jekyll into Mr. Hyde. For. Chron. 76(3):433–443. http://pubs.cif-ifc.org/doi/abs/10.5558/tfc76433-3

"In forested ecosystems, insects and pathogens play an important role in ecosystem function, and there is increasing evidence that these organisms are primary determinants of forest structure and composition. Recent research has confirmed this even in sub-boreal forests, where fire was traditionally thought to be the major agent of disturbance and hence the main driver of successional processes. This paper presents a conceptual model of biotic disturbance ecology in sub-boreal forests of central B.C. We also describe how forest management practices can lead to forest health problems by disrupting these ecological processes, and the natural population dynamics of insects and pathogens."

Lindgren, S. and K.J. Lewis. 1997. Ecological processes in the McGregor Model Forest: interactions with insects and pathogens. McGregor Model Forest Association, Prince George, B.C. www.resourcesnorth.org/publications/InteractionsWithInsectsAndPathogens.pdf

"The purpose of this synthesis paper is to provide a summary of the current knowledge or hypotheses regarding the interactions of insects and diseases with natural ecological processes, and to make some general interpretations with respect to ecosystem function. The development of any model that attempts to describe natural processes is difficult because of the complexity of natural systems, the interrelationships that exist between various components, and the different perspectives that result when the system is viewed at different temporal and spatial scales. For example, beetle outbreak and resultant mortality on an area when viewed over a short time period is seen to have one effect on the system, but when the same area is viewed over a time span of 300 years, the effect is seen differently. Therefore we have to be careful to define spatial and temporal scales when discussing or modelling agents of ecosystem or landscape change.

A landscape is normally thought of as a somewhat arbitrary area encompassed by a view or scenery. In the discipline of landscape ecology, the term landscape has been formalized in order to make the term useful. Thus, a

landscape is an area of land, which contains a repetition of a given set of attributes. When the set of attributes change, the landscape is also changed. In the McGregor Model Forest, we are concerned with the forested landscape. The attributes of this landscape, in a retrospective context, would be a mosaic of forested areas of various ages. Each unit of this mosaic consists of a number of similar stands, with a similar successional history. Therefore, we also discuss agents of change that occur at a stand level but that affect the overall landscape."

Lloyd, D., K. Angove, G. Hope, and C. Thompson. 1990. A guide to site identification and interpretation for the Kamloops Forest Region. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 23. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh23.htm

"The SBSmm is located on the west side of the North Thompson River, from Mann Creek (TFL 18) south to Eakin Creek. It also occurs on the north-facing slopes, including Reg Christie Creek, southeast of Vavenby." On dry sites "as a result of fire, dense, mature seral stands of Pl [lodgepole pine] exist."

Meidinger, D., A. McLeod, A. MacKinnon, C. DeLong, and G. Hope. 1988. A field guide for identification and interpretation of ecosystems of the Rocky Mountain Trench, Prince George Forest Region. B.C. Min. For. Lands, Res. Br., Victoria, B.C. Land Manag. Handb. 15. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh15.htm

"The SBSdh is found in the valley bottom of the Rocky Mountain Trench between Albreda and McBride, and the lower elevations of the northeast wall of the trench between Valemount and Dunster. The elevation ranges from a minimum of about 700 m along the Fraser River to approximately 1370 m." "Because of the extensive fire history of the subzone, the dominant trees are lodgepole pine and Douglas-fir. Although they are primarily seral species in this subzone, they do form the climax canopy on drier sites. Because of the fire history in the area, hybrid white spruce and subalpine fir climax stands are rare, only occurring as pure stands on wetter sites or on cooler northeast aspects."

Newbery, J. 2002. Small scale disturbances and stand dynamics in *Inonotus tomentosus* infected and uninfected old-growth and partial cut wet, sub-boreal forests in British Columbia. MSc thesis. Univ. Northern British Columbia, Nat. Resourc. Manag., Prince George, B.C. www.collectionscanada.gc.ca/obj/s4/f2/dsk4/etd/MQ80681.pdf

"Disturbance and stand dynamics were compared for old-growth and partial cut forests with and without *Inonotus tomentosus* (Fr.) Teng caused root disease in wet, cool Sub-Boreal Spruce forests near Prince George, British Columbia, Canada. Two methodologies (a time since death model and tree ring growth rate criteria) were developed to support two studies – a gap level analysis and a stand level analysis. The objectives of the studies were to: 1) Determine the spatial and temporal patterns of small-scale disturbance in old-growth and partial cut forests with and without the influence of *I. tomentosus*; 2) Determine how stand composition and structure differ between *I. tomentosus* infected and non-infected old-growth forests; 3) Determine how

I. tomentosus affects stand dynamics in partial cut forests and how its effects differ from its effects in old growth forests.

In the gap level analysis, four forest types were sampled in 10 meter fixed radius plots (Old-growth with *I. tomentosus* (OGT) (n=21), and partial cut with *I. tomentosus* (PCT) (n=22), Old-growth without *I. tomentosus* (OGNT) (n=23) and partial cut without *I. tomentosus* (PCNT) (n=23)). *P. glauca* × *engelmannii* mortality was 50% lower in partial cut forests than in old-growth forests regardless of infection status. The functional gap size caused by a single tree averaged 16.76 m^2. Summed gap-size measures for all trees dying in a decade indicated that between 6.9 and 8.1% of stand area was made available to understory trees per decade. Due to high mortality rates and low recruitment rates to the canopy for *P. glauca* × *engelmannii*, old-growth forests are shifting to a canopy dominated by *A. lasiocarpa*. In the partial cut plots, higher relative *P. glauca* × *engelmannii* recruitment and lower mortality indicate that *P. glauca* × *engelmannii* populations may rise relative to present densities.

In old-growth forests, the spatio-temporal patterns of canopy disturbance and canopy patch structure were quantified from 0.49 ha (n=6) stem-mapped plots using Moran's I and Standard Normal Deviates. Canopy disturbance and canopy composition were similar for *I. tomentosus* infected and uninfected stands at low levels of incidence. For stand types pooled, average decadal canopy disturbance ranged from 5.09%-6.0%. Gaps size averaged < 7 m in diameter and were irregularly distributed across the forests. Species patch structure analysis indicated that *P. glauca* × *engelmannii* is found in small patches which are probably remnants of a once nearly homogenous spruce canopy. These results show that small-scale disturbances are important successional mechanisms in old-growth Sub-Boreal Spruce forests because of their effects on stand structure and dynamics."

Newbery, T., K. Lewis, and M. Walters. 2002. Disturbance and stand dynamics in old-growth and partial cut wet, sub-boreal forests: the effects of *Inonotus tomentosus*. In: 4th Int. workshop on disturbance dynamics in boreal forests: disturbance processes and their ecological effects. Aug. 9–14, 2002, Prince George, B.C., p. 52.

"Disturbance patterns and stand dynamics were compared for old-growth and partial cut sub-boreal forests (SBSwk1) using two independent methodologies. The objectives of the study were to: 1) Quantify and compare the spatio-temporal patterns of small-scale disturbance and stand dynamics in old-growth and partial cut forests with and without the influence of *I. tomentosus* and; 2) Determine how stand composition and structure differ between *I. tomentosus* infected and uninfected old-growth forests. In a gap-level study, four forest types were sampled: 1) old-growth with *I. tomentosus* (OGT) (n=21), 2) partial cut with *I. tomentosus* (PCT) (n=22), 3) old-growth without *I. tomentosus* (OGNT) (n=23) and 4) partial cut without *I. tomentosus* (PCNT) (n=23).

P. glauca × *engelmannii* mortality was 50% lower in partial cut forests than in old-growth forests. Single tree gap size averaged 16.76 m^2 and cumulative gap area was between 6.9 and 8.1% of stand area per decade. Due to high mortality and low recruitment of *P. glauca* × *engelmannii*, old-growth forests are shifting to a canopy dominated by *A. lasiocarpa*. In the partial cut plots, higher relative *P. glauca* × *engelmannii* recruitment and lower mortality indicate that *P. glauca* × *engelmannii* populations may rise relative to present densities. In a stand-level analysis (n=6) sampled in old-growth forests exclusively, disturbance patterns and canopy composition were similar for *I. tomentosus* infected and uninfected stands. Average decadal canopy disturbance ranged from 5.0 to 6%. Average gap size was < 35.5 m^2 and gaps were irregularly distributed across the forests. While *I. tomentosus* is a significant cause of tree mortality in some stands, its pattern of disturbance was not distinguishable from other disturbance."

Newbery, J.E., K.J. Lewis, and M.B. Walters. 2007. *Inonotus tomentosus* and the dynamics of unmanaged and partial-cut wet sub-boreal spruce–fir forests. Can. J. For. Res. 37(12):2663–2676.
www.nrcresearchpress.com/doi/abs/10.1139/x07-117

"For wet sub-boreal spruce–fir forests (white spruce (*Picea glauca* (Moench) Voss) × Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) – subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.)) in east-central British Columbia, we asked (*i*) do compositional and structural dynamics differ for unmanaged (UN) and partial-cut (PC) (50% removal 45 years before measurement) forests and (*ii*) how does *Inonotus tomentosus* Fr. (Teng) affect these dynamics? *Inonotus tomentosus* infected stands had 17% less spruce basal area ($P = 0.059$) than uninfected stands, but PC did not exacerbate *I. tomentosus* effects. PC and UN had similar live tree density, but UN had lower dead tree density. In all stands, snag longevity was typically <32 years, and ~40 years was required for dead wood to reach decay stage 3 or greater. UN was characterized by variable severity disturbances averaging ~8% of the canopy per decade. Management implications include the following: (*i*) harvest systems designed to emulate small-scale disturbance could remove trees at 8% of the canopy per decade, varied spatiotemporally, (*ii*) emulating dead wood abundance with partial cutting may be difficult given the impacts of partial cutting on dead wood abundance, and (*iii*) forests with moderate levels of *I. tomentosus* should not respond differently to harvesting than uninfected forests and thus require no special management."

Parminter, J. 1993. Fire history of Bowron Lake Park. B.C. Min. For., Res. Br., Victoria, B.C.
www.for.gov.bc.ca/hfd/library/documents/bib4291.pdf

"While exact boundaries could not always be located, at least two fires in 1898 and 1893 burned over much of the lower and middle elevations of the north-western portion of the park. An earlier fire, presumed to have been in 1848, burned northwest of Indianpoint Lake. Other burned areas were seen north and south of the west end of Isaac Lake but fire years could not be estimated."

"Along Kibbee Creek a fire-scarred lodgepole pine indicated a fire in about 1853. This could be the result of a small, and presumably lightning-caused, fire or be near the boundary of a crown fire which was reduced to a surface fire at that point. Neither possibility could be investigated in the time available.

In this [20th] century, a fire in about 1920 burned over the ridge along the west side of Bowron Lake, coming down to the lakeshore in the vicinity of the park headquarters buildings. For the most part, it only came partway downslope along the ridge."

Rogeau, M.-P. 2001. Fire history study—Mackenzie TSA, British Columbia. Prepared for Abitibi Consolidated Ltd., Mackenzie, B.C. Unpubl. rep.

"More than one fire regime was identified for the Mackenzie TSA. According to historical air photo information and Ministry of Forest fire occurrence statistics, trends in vegetation complexity, number of fires and age-class distribution, are best associated with the type of terrain." "The overall assessment revealed that the Rocky Mountain Trench is generally younger with a higher number of fires and a moderately to highly complex vegetation mosaic, the Interior Plateau is also fairly young, even more complex but with less fires. The Omineca Mountains are older, with a lesser number of fires than the Trench, but with a fairly similar vegetation complexity. Lastly, the Canadian Rockies, although affected by many fires, shows larger extents of older aged forest and a much lower vegetation complexity in general. In terms of forest age distribution, older forests are found in the mountains. The Cassiar Mountains, the Canadian Rockies and the Omineca Mountains show that 59, 53 and 49 percent of these forests respectively, are older than 140 years."

"The assessment of fire occurrence statistics in a regional context shows that the Mackenzie TSA is representative of the regional setting in terms of proportion of fire and burn area by fire size category." "When the information is evaluated by terrain types within the TSA, the Rocky Mountain Trench and Interior Plateau are the most lightning-caused fire prone and the Trench and the Upper Trench are by far the most prone to anthropogenic fires." "The lightning strike density distribution evaluated for the Greater TSA shows almost no correlation with the occurrence of lightning caused fires."

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 1. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"The SBSdw is a relatively large subzone (approximately 6010 km^2 in the Cariboo Forest Region), which occurs on the gently rolling topography of the Fraser Plateau and southern Nechako Plateau near the southernmost limits of the SBS Zone. It extends from the southeastern portion of the Cariboo Forest Region (Bowers Lake area) northwestward to about the latitude of Prince George." "Climax forests are very uncommon due to frequent stand-initiating wildfires but, where present, are dominated by hybrid white spruce, subalpine fir, and scattered Douglas-fir. Seral stands are dominated primarily by Douglas-fir and/or lodgepole pine, although trembling aspen is also common. Douglas-fir and lodgepole pine stands are mostly single-storied with sparse to moderately dense tree regeneration consisting of sparse Douglas-fir and spruce and often abundant subalpine fir."

"The SBSmh Subzone occurs on the lower slopes and valley floors of the Fraser River valley, north of Alexandria, and the Quesnel River valley, downstream of about Quesnel Forks. It is the lowest-elevation subzone of the SBS in the Cariboo Forest Region." "Deciduous forests of trembling aspen and/or white birch, often mixed with Douglas-fir, hybrid white spruce, and subalpine fir, occupy a large proportion of the SBSmh landscape, due partly to frequent wildfires and harvesting in the past."

"The SBSmw Subzone occurs in the northeastern portion of the Cariboo Forest Region, east of the Fraser River and north of the Quesnel River. It occurs on the middle and upper slopes of these river valleys as well as eastward across the northeastern Fraser Plateau as it rises toward the Quesnel Highland." "Climax forests of the SBSmw are dominated by hybrid white spruce and subalpine fir. However, as in most other subzones on the Fraser Plateau, climax forests are uncommon due to past wildfires. Seral forests are dominated by a mixture of Douglas-fir, lodgepole pine, hybrid white spruce, and subalpine fir. Trembling aspen and white birch are also common."

"The SBSwk in the Cariboo Forest Region occurs along the moist eastern edge of the Fraser Plateau and on lower valley slopes in the dissected topography of the adjacent Quesnel Highland, north of the Cariboo River." "Old forests of hybrid white spruce and subalpine fir are common on the SBSwk landscape. These forests have a moderate cover of shrubs and herbaceous species and a well-developed moss layer. Principal shrub species are black huckleberry, black gooseberry, black twinberry, and thimbleberry. Lodgepole pine is the principal seral species following wildfire and covers a large proportion of the landscape. Douglas-fir and deciduous species are uncommon."

Steen, O.A. and R. Coupé. 1997. A field guide to forest site identification and interpretation for the Cariboo Forest Region: Part 2. B.C. Min. For., Res. Br., Victoria, B.C. Land Manag. Handb. 39.
www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh39.htm

"The SBSdw1 extends across the Cariboo Forest Region as a diagonal band from the Lac des Roches area in the southeastern corner of the Region to the confluence of the Blackwater and Fraser rivers in the north-central portion of the Region." On zonal site series "the canopy of the climax forest is dominated by hybrid white spruce, together with a significant component of Douglas-fir. However, due to a history of frequent wildfires, most natural stands are less than 150 years old and dominated by Douglas-fir or lodgepole pine. In contrast to the IDF, the Douglas-fir stands are generally even-aged and single-storied. Hybrid white spruce and subalpine fir are principal species in the understory."

"The SBSdw2 is a narrow diagonal band along the west side of the SBSdw1 in the central and northern portions of the Cariboo Forest Region. It does not extend as far south as the SBSdw1 but occurs further northward into the Prince George Forest Region." On zonal site series "the old forest canopy is dominated by hybrid white spruce and Douglas-fir but, due to frequent wildfires in the past, stands less than 150 years old are common and have an even-aged Douglas-fir- or lodgepole pine-dominated canopy. Tree regeneration is primarily Douglas-fir and spruce but sometimes includes subalpine fir."

"The SBSmc1 is a small biogeoclimatic unit (419 km^2 in the Cariboo Forest Region) that occurs on local heights-of-land on the Fraser Plateau, east of the

Fraser River. It occurs in the vicinity of Bowers Lake, Little Timothy Mountain, upper Moffat Creek, and Dragon Mountain." On zonal site series "the climax forest canopy is dominated by hybrid white spruce and subalpine fir but, due to past fire history, most stands are younger and dominated by lodgepole pine with spruce and subalpine fir regeneration. Douglas-fir is occasionally present in the forest canopy at low elevations."

"The SBSmc2 is a relatively large biogeoclimatic unit that occurs primarily in the Prince Rupert and Prince George forest regions. In the Cariboo Forest Region (1205 km^2), it occurs on local heights-of-land west of the Fraser River in the north-central portion of the Fraser Plateau." On zonal site series "the climax forest canopy is dominated by hybrid white spruce and subalpine fir but, due to past fire history, most stands are younger and dominated by lodgepole pine with spruce and subalpine fir regeneration. The undergrowth has a sparse to moderate cover of shrubs, primarily black huckleberry and Sitka alder."

"The SBSmw is in the northeast portion of the Cariboo Forest Region and adjacent portions of the Prince George Forest Region. In the Cariboo Forest Region (1374 km^2), it extends eastward from the Quesnel River across the gently rolling landscapes of the Fraser Plateau to the western edge of the Quesnel Highland." On zonal site series "the climax forest canopy is dominated by hybrid white spruce and subalpine fir, although Douglas-fir is common as a long-lived seral species. Due to past fires, seral lodgepole pine and Douglas-fir stands are common. In all stands, subalpine fir is the most abundant species of tree regeneration."

"The SBSwk1 occurs in the northeastern portion of the Cariboo Forest Region and adjacent portions of the Prince George Forest Region. In the Cariboo Forest Region (1473 km^2), it dominates the rolling terrain along the western edge of the Quesnel Highland north of the Cariboo River. It also extends eastward in valley bottoms into the more dissected and rugged landscapes of the Quesnel Highland and Cariboo Mountains." On zonal sites "climax tree species are hybrid white spruce and subalpine fir. Spruce is the principal canopy species, while subalpine fir is the principal tree species in the regeneration layer. Subalpine fir as well as lodgepole pine are often present in the canopy. Since wildfires have been less frequent than in other portions of the SBS in the Cariboo Region, lodgepole pine stands are also less common."

Steventon, D. 1997. Historic disturbance rates for interior biogeoclimatic subzones of the Prince Rupert Forest Region. B.C. Min. For., Prince Rupert For. Region, Smithers, B.C. Exten. Note 26. www.for.gov.bc.ca/rni/research/Extension_notes/Enote26.pdf

"One important parameter of natural disturbance regimes is the frequency at which stand initiating events such as severe fire have historically occurred, and how this has shaped the age structure of forest landscapes. In this note, using the forest inventory database, I examine the historic rate of stand initiating disturbances in the SBPSmc, SBSdk/mc and ESSFmc/wk/mk Biogeoclimatic (BEC) subzones of the Lakes, Morice and Bulkley forest districts, Prince Rupert Forest Region."

Stand-initiating disturbance rates were calculated using all age data and then truncated age data, which account for possible biases in assigning ages to stands older than 160 years. Results were as follows: SBPSmc: 91 and 92 years; SBSdk: 93 and 95 years; SBSmc: 124 and 148 years; ESSFmc: 166 and 284 years; ESSFmk: 337 and 810 years; and ESSFwv: 220 and 1150 years (for all age data and truncated data, respectively). The considerable differences for the last two ESSF subzones are due to the large areas of stands older than 240 years for which the true ages are not known.

Thompson, R.D. 2005. Fine-scale disturbance and stand dynamics in mature, spruce–subalpine fir forests of central British Columbia. MSc thesis. Univ. Northern British Columbia, Nat. Resourc. Environ. Stud., Prince George, B.C.

www.collectionscanada.gc.ca/obj/thesescanada/vol2/002/MR28390.pdf

"Fine-scale disturbance and stand dynamics within mature, spruce-subalpine fir forests were compared and contrasted across the central interior of British Columbia. The central interior is ideal for the study of fine-scale disturbance because sub-boreal and subalpine ecosystems span the dry interior plateau and grade eastward into the progressively wetter, cooler, high-elevation ecosystems of the Rocky Mountain Foothills. Three biogeoclimatic variants where selected across this climatic gradient: the dry-warm Sub-Boreal Spruce (SBSdw3), the wet-cool Sub-Boreal Spruce (SBSwk1), and the wet-cool Engelmann Spruce-Subalpine Fir (ESSFwk2). Traditional and newly developed dendroecological techniques were used to identify the effects of past intermediate- and coarse-scale disturbance events, and to infer regional climate fluctuations, in order to separate these from the effects of fine-scale disturbance. Periods of canopy mortality occurred in the ESSFwk1 variant during the 1710s and 1830s, in the SBSwk1 variant during the 1830s and 1870s, and in the SBSdw3 variant during the 1870s. Based on historical documentation and dendroecological evidence, these periods of canopy mortality were likely caused by spruce beetle, and there is strong evidence of notable shifts in species composition.

A western balsam bark beetle outbreak occurred in the ESSFwk2 variant during the 1920s and 1930s, and tree ring analyse provides strong evidence that species dominance shifted from subalpine fir to spruce within these stands. Moran's I analysis of canopy ascension dates suggests that fine-scale disturbance is random in space and time across all ecological variants. Canopy openings caused by disturbance averaged ~2.5 m in diameter, which is equivalent to the average distances between nearest neighbours. Decadal disturbance rates did not differ by variant (p = 0.117) or by species nested within variant (p = 0.418). Although the decadal disturbance rates did not differ by variant, mean rates within SBSdw3, SBSwk1, ESSFwk2 variants were 7.4, 6.4 and 5.0%, respectively. The results of this research indicate that fine-scale disturbances are important ecological processes in sub-boreal and subalpine forest ecosystems. Within these ecosystems, however, there is considerable overlap between disturbance types of varying spatial and temporal scales. Intermediate- and coarse-scale disturbance events, such as those caused by insects (e.g., spruce beetle and western balsam bark beetle), have been more influential in causing distinct changes in stand structure and composition than fine-scale disturbances. Consideration of disturbance events at multiple scales, however, shows that fine-scale disturbance does exhibit continuous stand level maintenance and renewal."

Vasbinder, W.J. 2001. Forest fire in the mountain ranges of northeastern British Columbia: a historical perspective. MSc thesis. Univ. Northern British Columbia, Nat. Resourc. Manag., Prince George, B.C.

"In an effort to sustain biological diversity, it has been proposed that the impacts of forest management approximate the effects of natural disturbances. This study has investigated mountainous sub-boreal spruce (SBSvk) and Engelmann spruce-subalpine fir (ESSFwk2/wc3) biogeoclimatic units in north-eastern British Columbia in an effort to provide information on historical fire regimes. This information may help in the development of forest management plans that better approximate ecological processes. The influence of topography on the spatial and temporal extent of seral age-class patches and contemporary lightning-caused fires was a primary focus in this study.

Natural disturbance patch characteristics were described and estimates were calculated of the periodicity of stand-initiating disturbances. A digital elevation model was constructed for the study area and related to age-class information derived from forest cover data, as well as lightning-caused fire location data for the period of 1950-1992.

Results showed strong spatial differences in natural disturbance patch characteristics based on landscape orientation. Patch characteristics for both eastern and western slopes of the Rocky Mountains indicated that current estimates of patch size distributions and the periodicity of stand-replacing disturbances do not well approximate historical landscape patterns for the 100 year period prior to 1950. Topography was revealed to have a strong relationship with age-class patch size on western slopes, but it was only weakly correlated with other patch characteristics on western and eastern slopes. The topographical associations of lightning-caused fires and seral patches were somewhat similar, but could not provide conclusive evidence that fires initiated younger forest patches. The dominance of old-growth forest age-classes in the study landscape provided support for the importance of fine-scale or non-stand replacing natural disturbances in the maintenance of forest structure and composition. Explicit consideration of landscape characteristics is recommended in future attempts to approximate natural disturbances."

Vasbinder, W., B.C. Hawkes, and C. Opio. 1998. Influence of topography upon the historical fire regime of the SBSvk and ESSFwk2/wc2 biogeoclimatic subzones, British Columbia. In: Ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. Workshop proc. M. Jull, D. Coxson, S. Stevenson, D. Lousier, and M. Walters (editors). UNBC Press, Prince George, B.C., p.18.
http://web.unbc.ca/~wetbelt/docs/1997-Wetbelt-Workshop-Proceedings.pdf

"A retrospective study of fire was initiated in the north-eastern interior of British Columbia as a part of the McGregor Model Forest's larger effort to determine the ecological processes that influence the forest landscape in this area. This study seeks to define and quantify historical disturbance patch size, pattern, and frequency in the SBSvk and ESSFwk2/wc3 biogeoclimatic subzones, and to evaluate the influence of topography upon these elements of the fire regime."

"The study area encompasses approximately 1.3 million hectares of forested and mountainous terrain stretching along the western side of the Rocky Mountains from McBride, BC in the southeast to Pine Pass in the northwest, and an area of the eastern slopes and foothills which extends north-east to the vicinity of Chetwynd, BC. British Columbia Ministry of Forests digital forest inventory data is being heavily relied upon to determine the age and patch characteristics of the study landscape." "Preliminary results indicate that the fire cycle for these cool and wet mountain subzones seems to be longer than initially estimated. The fire cycle for these areas could be as long as 560–700 years. Disturbance patch sizes for the study area are small, with 51% of disturbance patches 1–9 ha in size. Patch size seems to exhibit a north-south gradient over the study area with the northern half of the study area characterized by larger areas of disturbance than the southern half of the study area. It appears that northern patch size results are being influenced by the much larger disturbance patches found on the east slopes of the Rocky Mountains."

Wong, C. 2000. Natural disturbance regimes in the Cariboo region: what is known to guide forest management? Prepared for Lignum Ltd., Vancouver, B.C. Unpubl. rep.

"In general, the quality and quantity of data on past natural disturbance regimes are poor in the Cariboo. Most data are from studies which have not been peer reviewed, meaning the quality of the data is uncertain. Not enough data exists to describe the historical temporal and spatial variability in disturbance regimes over different biogeoclimatic variants and topographic positions in the Cariboo Forest Region and in Lignum's IFPA area. The data that do exist illustrate that there is temporal and spatial variability in forest dynamics and disturbance regimes in the Cariboo. Some conclusions about past natural disturbance regimes were possible:

1. Small shifts in climate (e.g., 2 - 4°C increase in temperature) can drive variability in forest composition and disturbance regimes over long time scales (e.g., > 1000s of years).
2. Historical patterns in temperature and precipitation over the last 500 years have not been reconstructed yet from tree rings in the Cariboo.
3. Tree encroachment into grasslands since the 1960s, particularly in wet sites and on northern aspects, has decreased grassland by approximately 30% over areas of the Fraser and Cariboo Basin ecosections. Open, closed and aspen forests varied in whether they increased or decreased.
4. The frequency of low-severity fires in 14 Cariboo stands varied over space. Between 1717 and 1900, the mean fire interval ranged from 7 to 29 years, median 15 years. Including fires after 1900, the median MFI increased to 21 years, suggesting fire exclusion has occurred in the Cariboo. The last fires in the stands occurred 1911 - 1968.
5. On the Chilcotin Plateau, 9 – 24% of a large SBPSxc and MSxv landscape was likely cumulatively burned by small (< 120 ha) and large (> 1000 ha) high-severity fires over any given 20 year period between 1850-1950. This

is similar to the SBSmk1 in the Prince George Region but peak periods of disturbance differed. Fire creates more complex spatial patterns on the sub-boreal landscape than traditional clearcutting; e.g., refugia from fires in the 1930s and 1950s, comprise 3-15% of burned areas and were 1-73 ha in size in the SBSmk1 in the Prince George Region.

6. There are not enough data to determine historical insect and disease disturbance regimes in the IFPA area. Patterns in tree rings indicate that widespread, high-severity outbreaks of spruce bark beetle occurred infrequently in the past (1720s, 1810-1820, 1960-1980s) in the Prince George region.
7. The IDF in the IFPA area east of the Fraser River has the potential to be relatively frequently disturbed every year to every 40 years by either fire or extreme wind events.
8. Traditional burning for maintaining meadows and open forests did occur in early spring around Canoe Creek, southern part of the IFPA area east of the Fraser River."

Zhang, Q.-B. and R.I. Alfaro. 2002. Periodicity of two-year cycle spruce budworm outbreaks in central British Columbia: a dendro-ecological analysis. For. Sci. 48(4):722–731.
www.ingentaconnect.com/content/saf/fs/2002/00000048/00000004/art00010

"An outbreak of the two-year cycle budworm (*Choristoneura biennis* Freeman) has caused defoliation damage to interior spruce (*Picea engelmannii* Parry × *P. glauca* (Moench)) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) forests of north central British Columbia for more than 10 yr and was ongoing in 1999. A sample of 429 increment cores from spruce, subalpine fir, and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) was collected in areas of chronic defoliation, and used in a dendro-ecological study. The objective was to develop accurately dated ring-width chronologies of each species and, by comparing growth rates of the budworm host tree species (spruce and fir) with those of the nonhost pine, to determine the past history of budworm outbreaks in the region. This history would help in estimation of the potential duration and severity of the current outbreak in the region.

Four periods of decade-long reduced growth attributable to budworm defoliation were identified in the increment cores from both spruce and subalpine fir. These occurred in the mid-1890s to the early 1900s, the mid-1920s to the mid-1930s, the 1950s to the early 1960s, and the late 1980s to present (1999). Outbreaks recurred approximately every 32 yr. The reduced growth period, indicative of past outbreaks, consisted of a growth reduction phase lasting 7 to 11 yr in which rings generally exhibited a pattern of alternating wide and narrow rings (a 'saw-tooth' pattern). This pattern was attributed to the biennial nature of the life cycle of this budworm, in which severe damage is caused every other year. The growth reduction phase was followed by a growth recovery phase lasting 3 to 5 yr in which ring-width gradually returned to pre-outbreak levels. Thus, the entire growth loss period could last from 10 to 16 yr and cause an average annual loss in radial increment from 16 to 21%. The 32 yr cycle of outbreak recurrence was attributed to changes in forest structure in which the forest evolves from a nonsusceptible to a susceptible state as the proportion of subalpine fir present in the upper canopy increases relative to the spruce component. A 2 yr cycle budworm outbreak will selectively remove the subalpine fir component returning the forest to a less susceptible state. It was concluded that the 2 yr cycle budworm is an important disturbance agent of northern British Columbia forests causing significant growth loss."

Zhang, Q., R.I. Alfaro, and R.J. Hebda. 1999. Dendroecological studies of tree growth, climate and spruce beetle outbreaks in Central British Columbia, Canada. For. Ecol. Manag. 121(3):215–225. www.sciencedirect.com/science/article/pii/S0378112798005520

"Dendroecological techniques were used in this study to compare the radial growth patterns of different conifer species and to identify regional climatic anomalies and spruce beetle (*Dendroctonus rufipennis* Kirby) outbreaks for the past four centuries in the McGregor Model Forest, central British Columbia, Canada. Tree-ring chronologies of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), and interior spruce (*Picea engelmannii* Parry × *P. glauca* (Moench) Voss) were developed for the Model Forest. Response function analysis showed that (1) Douglas-fir is the most climate sensitive species, and its radial growth is mainly controlled by spring precipitation and early summer temperature, and (2) the ring growth of subalpine fir and spruce is negatively affected by high summer temperature. Comparisons of the tree-ring chronologies among the three species revealed dynamics of growth releases and suppressions which reflected climate variations and forest disturbance patterns in the past several centuries. The climate during the late 1750s–1800s was characterized by slightly moist springs and probably moderate summers. During the late 1860s and early 1870s, the region experienced dry springs, hot summers, and probably cold late falls. This study identified three intervals of major disturbances attributable to severe spruce beetle outbreaks: the late 1720s, 1810s–1820s, and 1960s-early 1980s. These coincided with periods of above average growth in Douglas-fir. The association suggested a possible moist spring-outbreak pattern. The multicentury tree-ring records of climate anomalies and spruce beetle outbreaks could provide insight into the dynamics of forest growth and its response to environmental changes."